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# **LESSON 6**

## ***Site Selection for PM<sub>10</sub> Monitoring Stations***

### ***Goal***

To familiarize you with the siting of PM<sub>10</sub> monitoring stations.

### ***Objectives***

At the end of this lesson, you will be able to:

- 1 list in sequence the six major steps in selecting PM<sub>10</sub> monitoring sites.
- 2 recognize the usefulness of historical particulate matter monitoring and emissions data in selecting PM<sub>10</sub> monitoring sites.
- 3 describe two techniques for analyzing historical particulate matter monitoring data in selecting PM<sub>10</sub> monitoring sites.
- 4 identify data concerning particulate emissions, topography, and meteorology that are needed to determine if historical particulate matter measurements are adequate for selecting a PM<sub>10</sub> monitoring site.
- 5 discuss analytical techniques for determining whether historical particulate matter measurements are adequate for selecting a PM<sub>10</sub> monitoring site.
- 6 recognize six limitations of model simulations in selecting PM<sub>10</sub> monitoring sites.
- 7 explain why modeling results are not needed to select a regional scale PM<sub>10</sub> monitoring site.
- 8 select the general siting areas for regional scale PM<sub>10</sub> monitoring stations.
- 9 select the general siting locations for neighborhood scale, middle scale, and microscale PM<sub>10</sub> stations in urban areas.
- 10 recognize general siting considerations for locating PM<sub>10</sub> monitoring stations for isolated point sources in flat and in complex terrain.
- 11 recognize the usefulness of temporary monitoring and mobile sampling for determining monitoring site locations.
- 12 list information that should be included in a site description document for a PM<sub>10</sub> monitoring station.

## ***Procedure***

- 1 Read pages 44-100 of EPA-450/4-87-009 *Network Design and Optimum Site Exposure Criteria for Particulate Matter*.
- 2 Complete the review exercise for this lesson.
- 3 Check your answers against the answer key following the exercise.
- 4 Review the pages in the reading for any questions you missed.
- 5 Continue to Lesson 7.

***Estimated student completion time: 4 hours***

## ***Reading Assignment Topics***

- Using historical particulate matter air monitoring and emissions data to locate PM<sub>10</sub> monitoring stations
- Using air quality models to locate PM<sub>10</sub> monitoring stations
- Locating regional scale PM<sub>10</sub> monitoring stations
- Locating PM<sub>10</sub> monitoring stations in urban areas with no major point sources
- Locating PM<sub>10</sub> monitoring stations for isolated point sources in flat terrain
- Locating PM<sub>10</sub> monitoring stations for isolated point sources in complex terrain
- Locating PM<sub>10</sub> monitoring stations in urban areas with major point sources
- PM<sub>10</sub> sampler placement
- PM<sub>10</sub> monitoring site description
- Example PM<sub>10</sub> site selection study

## Reading Guidance

Refer often to figures 15, 17, 18, 19, 20, 21, and 23 while reading the assigned material.

The statement on page 57 of the assigned reading material concerning the lack of IP specific emission factors and emission data is no longer correct because of PM<sub>10</sub> emission data that have been obtained since the publication of *Network Design and Optimum Site Exposure Criteria for Particulate Matter*.

Because *Network Design and Optimum Site Exposure Criteria for Particulate Matter* was published before the promulgation of the PM<sub>10</sub> portion of 40 CFR 58, the PM<sub>10</sub> sampler roadway setback distances specified in Table 15 of the document do not agree with the required setback distances of 40 CFR 58. Setback distances, as well as other sampler siting criteria specified in 40 CFR 58, are addressed in Lesson 7 of this book.

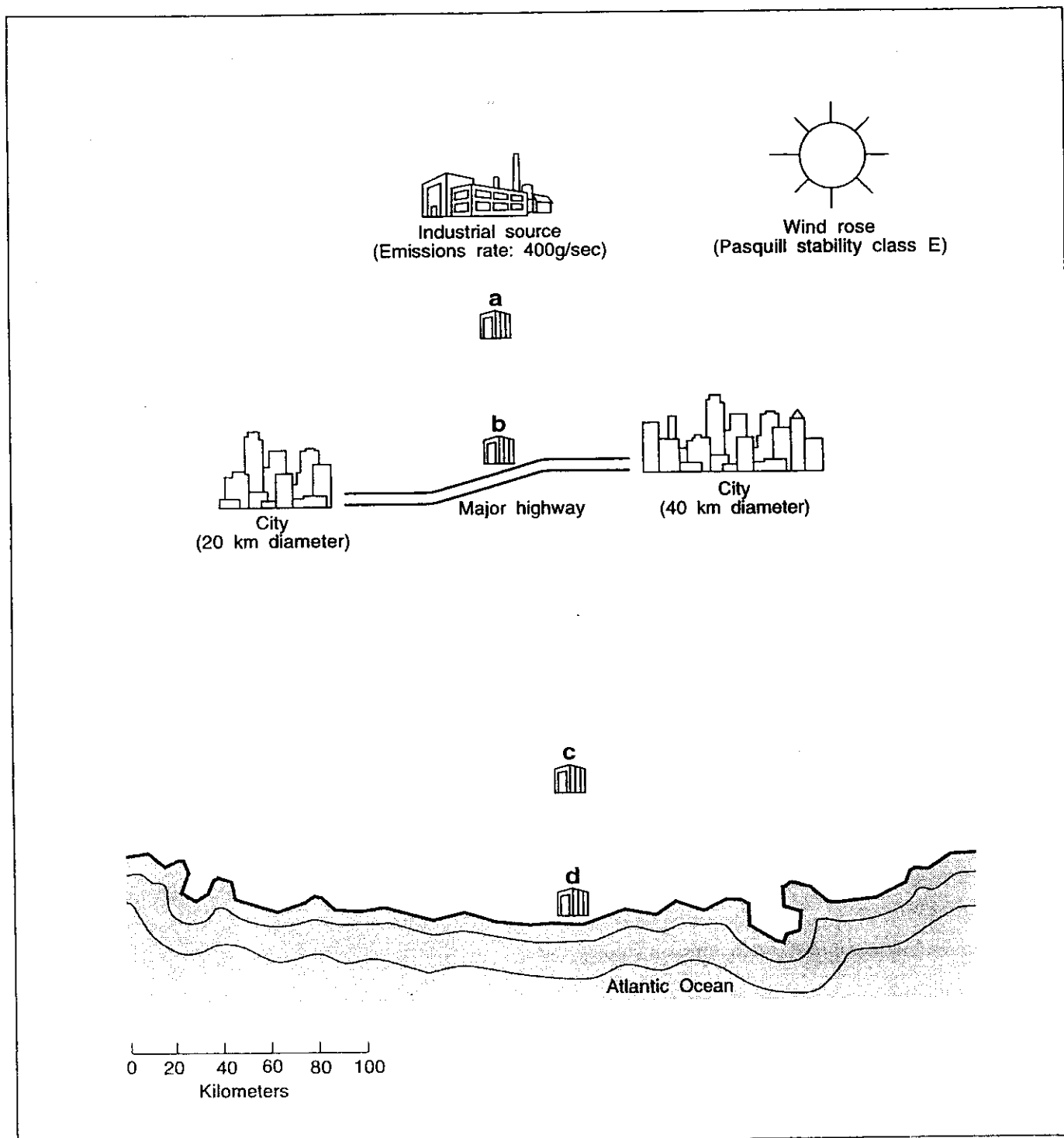
## Review Exercise

Now that you've completed the assignment for Lesson 6, please answer the following questions to determine whether or not you are mastering the material.

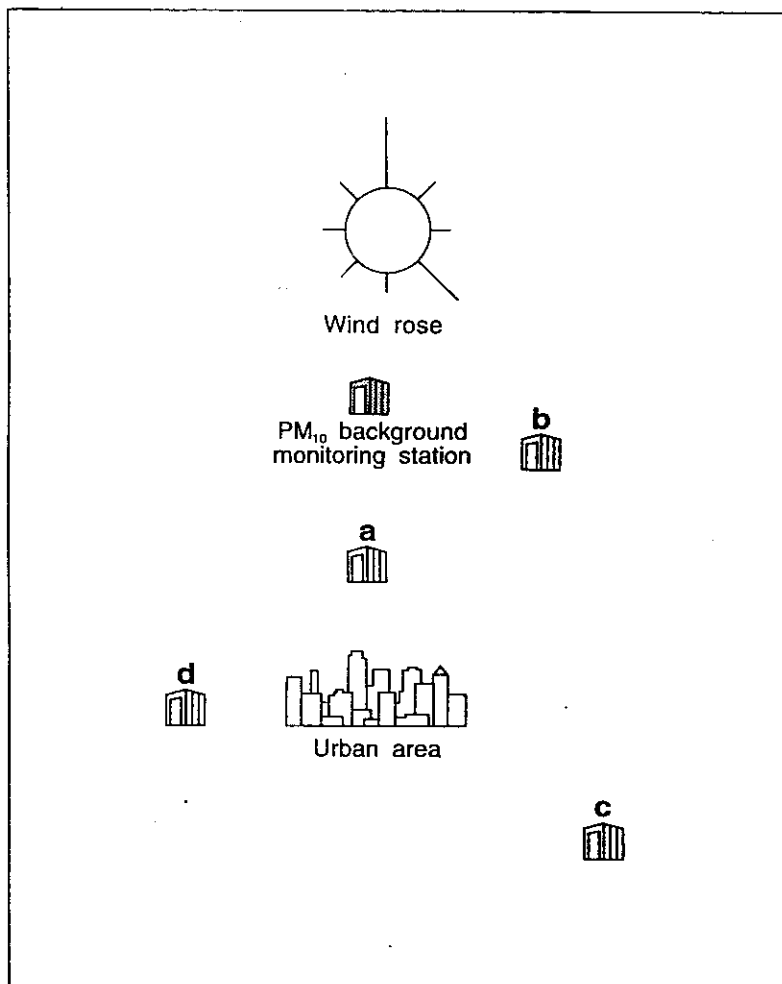
1. Which of the following is (are) the proper sequence(s) of major site selection steps for  $PM_{10}$  monitoring?
  - a. determine monitoring network requirements, determine monitoring sites and  $PM_{10}$  sampler placement, document and update site exposure experience
  - b. model air quality, determine monitoring sites and  $PM_{10}$  sampler placement, determine monitoring network requirements
  - c. analyze existing particulate matter monitoring data, review local situation to determine adequacy of mapping analysis and/or to select a modeling procedure, model air quality (if necessary)
  - d. a and b, above
  - e. a and c, above
2. Which of the following is (are) useful for selecting  $PM_{10}$  monitoring sites?
  - a.  $PM_{10}$  air monitoring data
  - b. IP emissions data
  - c. TSP air monitoring data
  - d. all of the above
3. Generally, performing a mapping analysis of historical particulate matter air monitoring data to select  $PM_{10}$  monitoring sites is not practical unless concurrent data are available from at least \_\_\_\_\_ sites.
  - a. 2
  - b. 4
  - c. 6
  - d. 8
4. Which of the following historical particulate matter maps should be constructed in selecting  $PM_{10}$  monitoring sites?
  - a. an annual means map
  - b. a peak, nonconcurrent 24-hour peak concentration map
  - c. a concurrent 24-hour concentrations map for days having one or more high concentrations
  - d. a and b, above
  - e. a and c, above
  - f. all of the above

5. True or False? Trends and frequency distributions of historical particulate matter concentrations measured at individual monitoring sites should be analyzed when using the particulate matter concentration data to select PM<sub>10</sub> monitoring sites.
6. True or False? U.S. Geological Survey maps, Sanborn maps, and aerial photographs can provide land use information for selecting PM<sub>10</sub> monitoring sites.
7. True or False? Fugitive emissions data are not needed for selecting PM<sub>10</sub> monitoring sites.
8. True or False? Census data and traffic data may be useful in defining the spatial distribution of particulate matter emissions.
9. Data from which of the following topographical features should be evaluated when using historical particulate matter air monitoring data to select PM<sub>10</sub> monitoring sites?
  - a. simple terrain features
  - b. shorelines of major bodies of water
  - c. boundaries of significant urban areas
  - d. b and c, above
  - e. all of the above
10. True or False? The single most significant meteorological parameter that must be homogeneous when using an air quality model to select PM<sub>10</sub> monitoring sites is wind speed.
11. Which of the following techniques should be used for determining the adequacy of historical particulate matter data in selecting PM<sub>10</sub> monitoring sites?
  - a. analyzing short-term air quality patterns over time for consistency
  - b. analyzing long-term air quality patterns over time for consistency
  - c. comparing emissions densities with air quality patterns to determine if reasonable relationships exist
  - d. a and c, above
  - e. b and c, above
  - f. all of the above
12. True or False? A reasonably consistent relationship between an emission densities pattern and an air quality pattern would be one in which the air quality pattern is offset from the emission pattern in the direction of prevailing wind flow.
13. Which of the following is a (are) limitation(s) of models that are used to select PM<sub>10</sub> monitoring sites?
  - a. uncertainty of fugitive emissions estimates
  - b. simplistic treatment of topographical influences of atmospheric transport and dispersion of pollutants
  - c. possible inadequate treatment of airborne particle removal by wet and/or dry deposition
  - d. a and b, above
  - e. all of the above

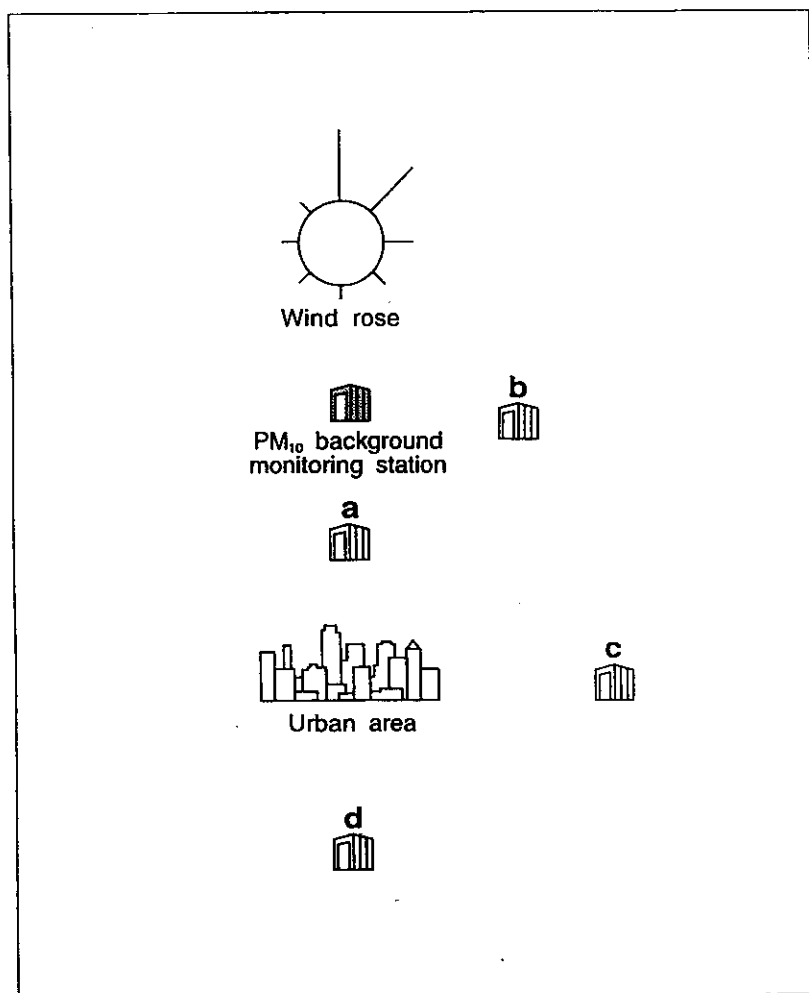
14. True or False? Modeling results are not needed to site regional scale  $PM_{10}$  monitoring stations because the influences of nearby  $PM_{10}$  emissions sources on such stations are negligible.
15. True or False? The most suitable site for a microscale/middle scale monitoring station for measuring maximum  $PM_{10}$  concentrations is within five meters of the upwind side of a  $PM_{10}$  emissions source.
16. Which of the four general siting areas, labeled a through d, is the best siting area for a  $PM_{10}$  regional scale monitoring station?



17. Which of the four general siting areas, labeled a through d, is the best siting area for locating a *second* regional scale monitoring station for assessing background PM<sub>10</sub> concentrations?

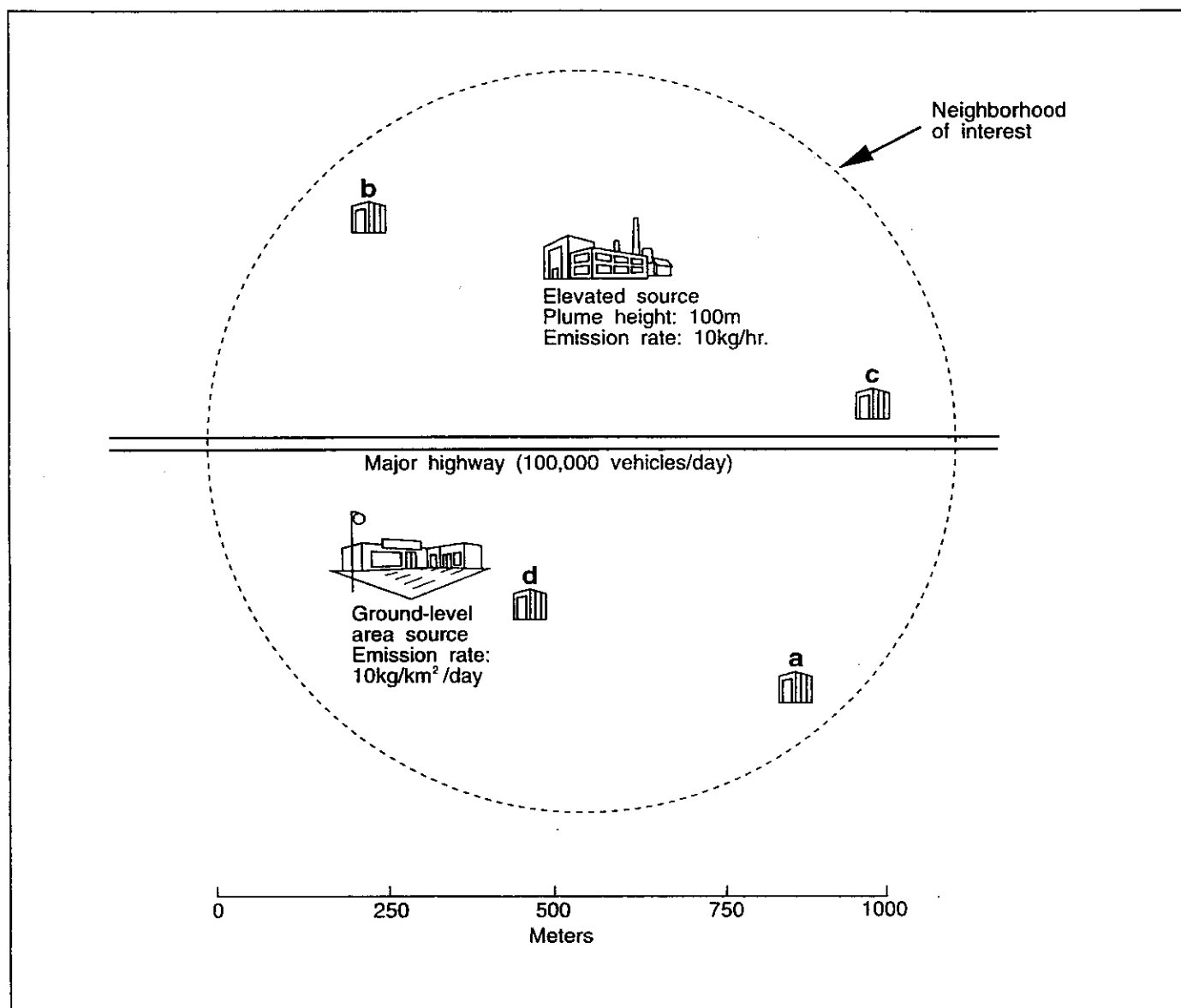


18. Which of the four general siting areas labeled a through d, is the best siting area for locating a *second* regional scale monitoring station for assessing background  $PM_{10}$  concentrations?

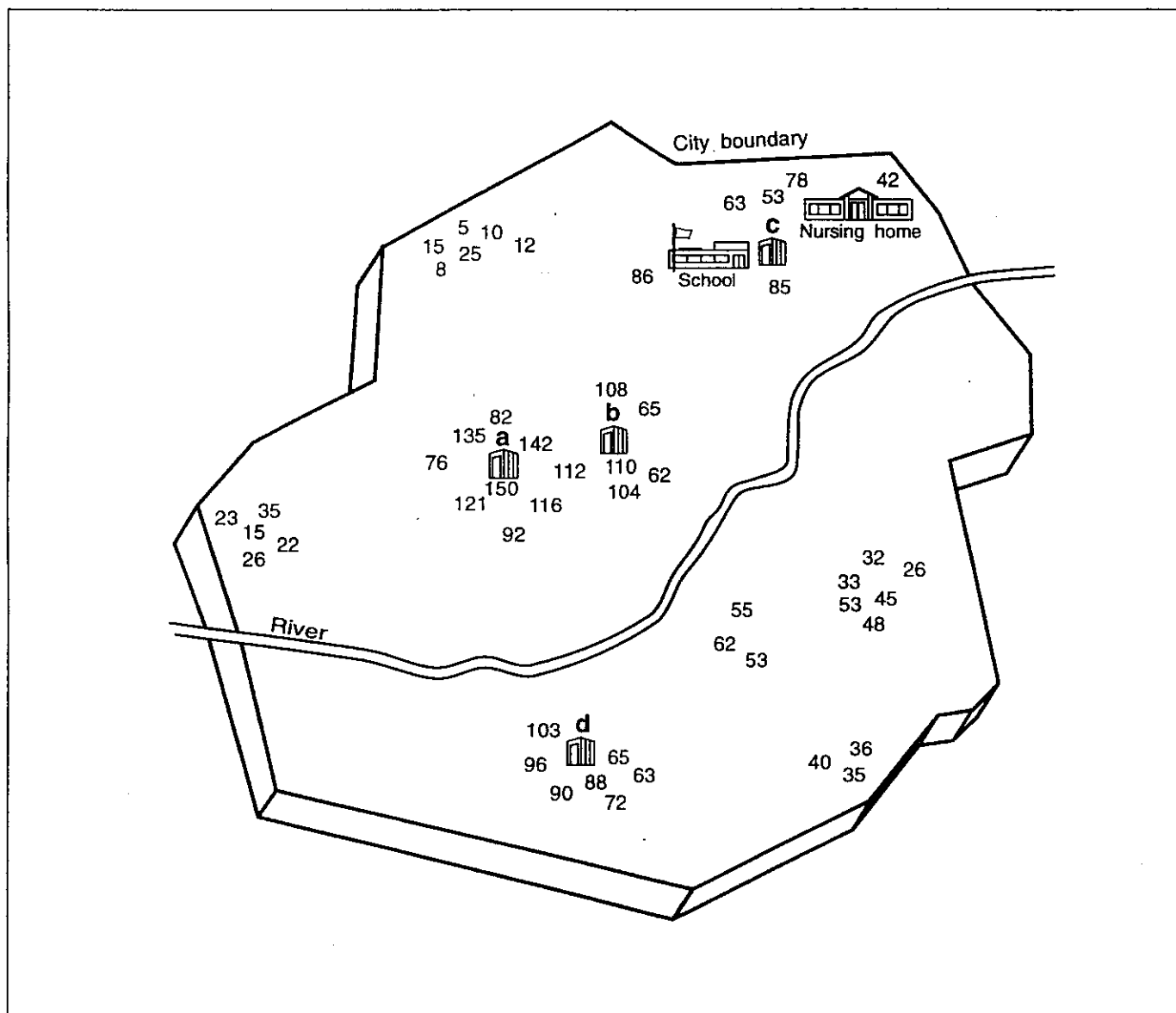




19. Which of the four general siting areas, labeled a through d, is the best siting area for a PM<sub>10</sub> neighborhood scale monitoring station?

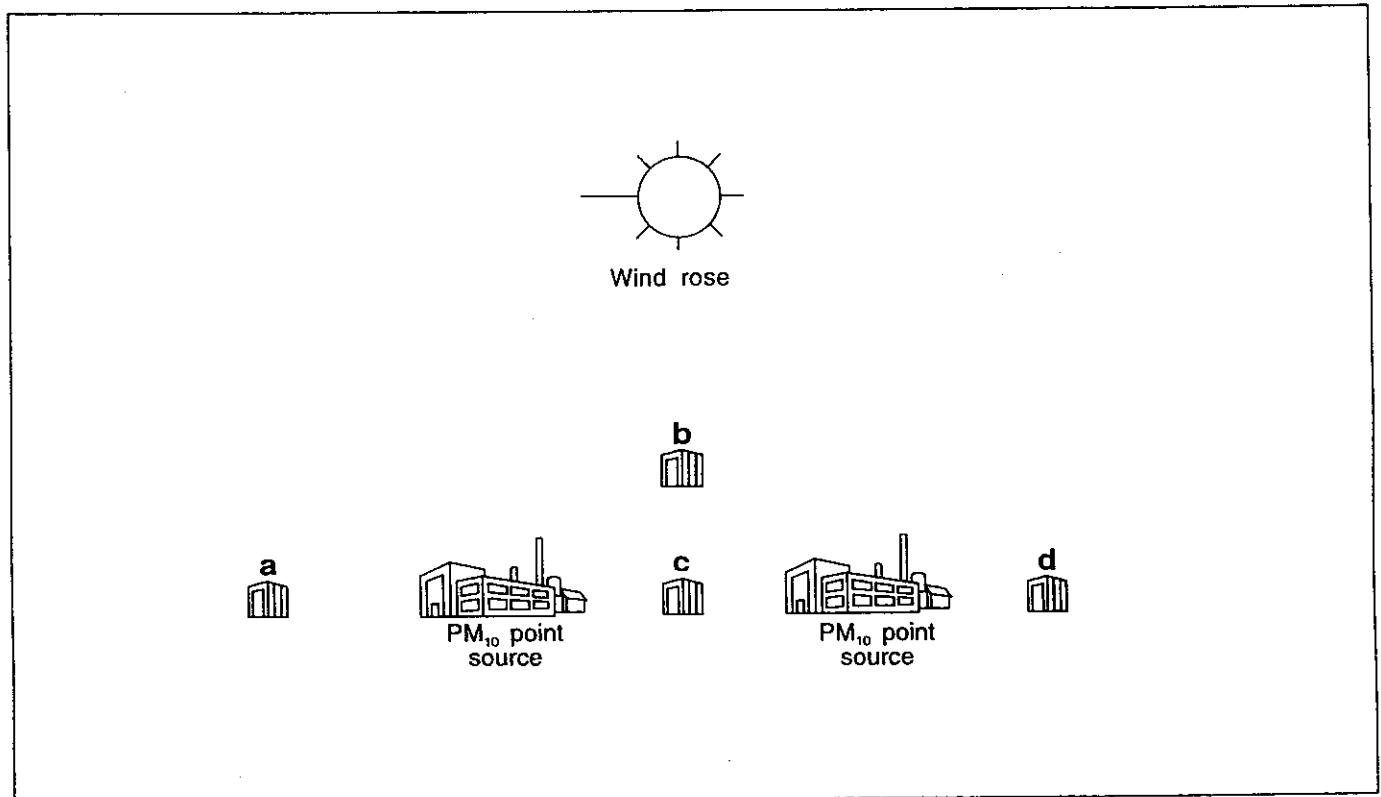


20. The figure below represents a city area with relative  $PM_{10}$  emission rates plotted. Which of the four general siting areas, labeled a through d, is the best site for locating a neighborhood scale  $PM_{10}$  monitoring station?



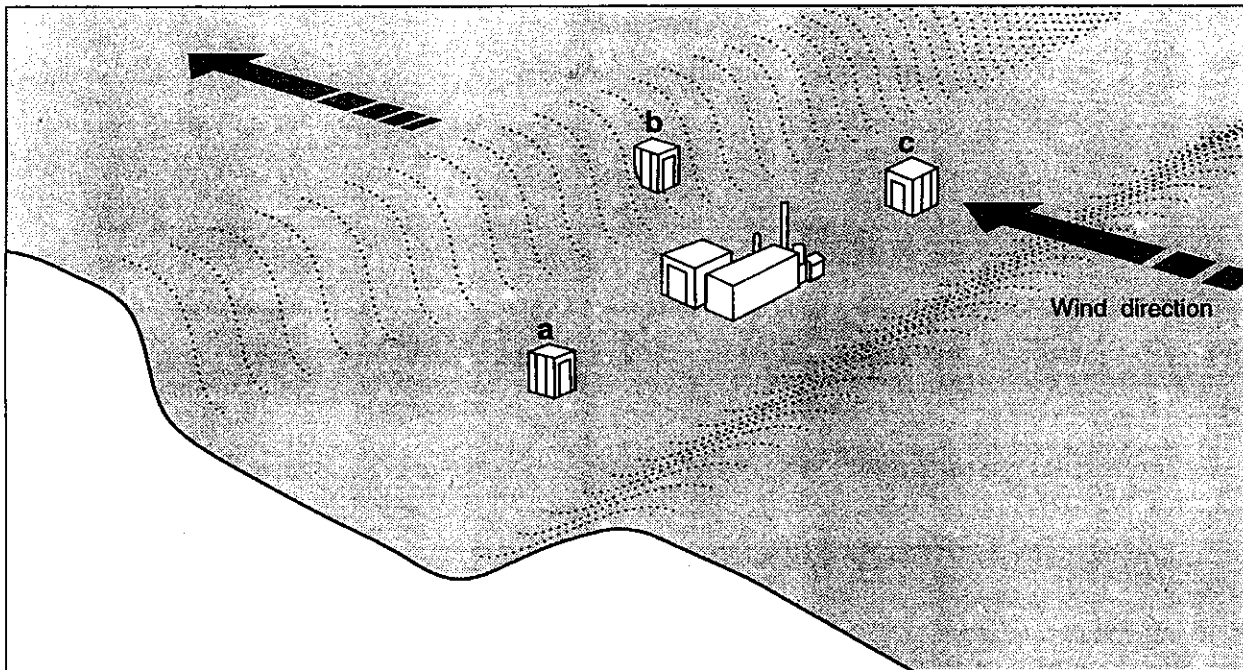
21. Which of the four general siting areas, labeled a through d in question 20, is the *second* best site for locating a neighborhood scale  $PM_{10}$  monitoring station?
22. Which of the four general siting areas, labeled a through d in question 20, is the *third* best site for locating a neighborhood scale  $PM_{10}$  monitoring station?

23. Which of the four general siting areas, labeled a through d, is the best siting area for a monitoring station for determining maximum 24-hour PM<sub>10</sub> concentrations resulting from the point sources?

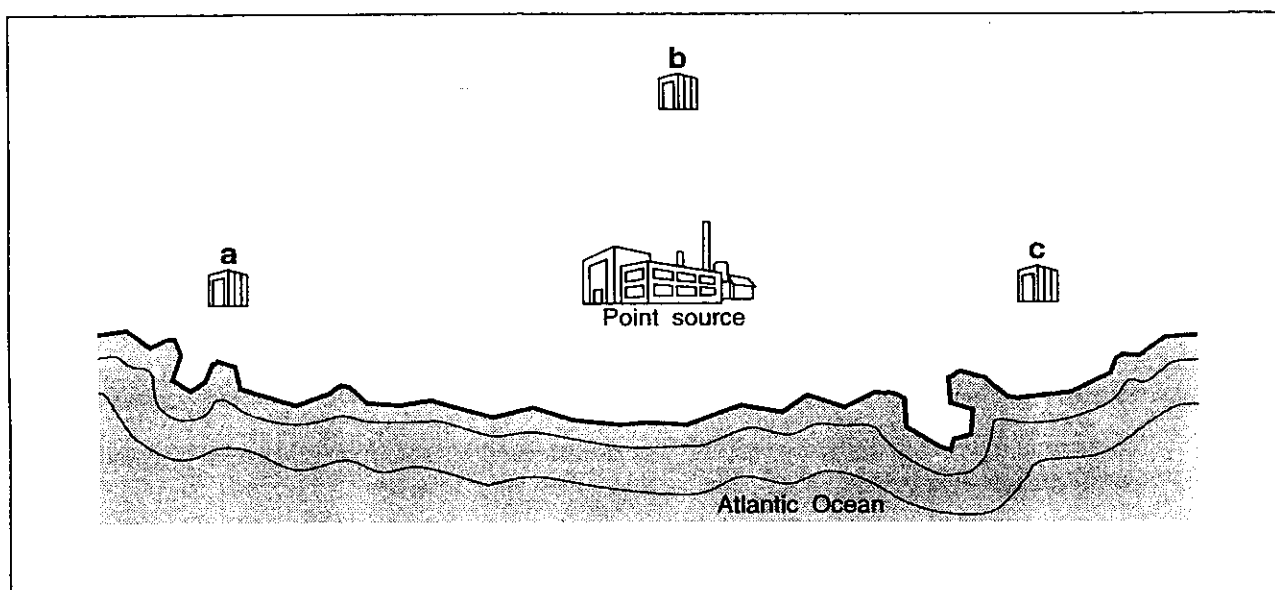


24. Which of the four general siting areas, labeled a through d in question 23, is the best siting area for a monitoring station for determining the maximum *annual* mean PM<sub>10</sub> concentration resulting from the point sources?

25. Which of the three general siting areas, labeled a through c, is (are) the best siting area(s) for determining maximum  $PM_{10}$  concentrations resulting from the point source?
- a. site a
  - b. site b
  - c. site c
  - d. all of the above



26. Which of the three general siting areas, labeled a through c, is (are) the best siting area(s) for determining maximum PM<sub>10</sub> concentrations resulting from the point source?
- a. site a
  - b. site b
  - c. site c
  - d. all of the above



27. Microscale influences within 100 meters of a  $PM_{10}$  ground-level source in flat terrain are at least \_\_\_\_\_ times greater than the middle scale influences from 100 to 500 meters of the source.
- 2
  - 5
  - 10
  - 100
28. True or False? To measure maximum  $PM_{10}$  concentrations during periods of unstable atmospheric conditions, it is necessary to locate monitoring stations close to  $PM_{10}$  point sources in flat terrain.
29. True or False? To measure maximum  $PM_{10}$  concentrations during periods of persistent winds, it is necessary to locate monitoring stations downwind of  $PM_{10}$  point sources in flat terrain at distances associated with maximum  $PM_{10}$  concentrations during periods of neutral atmospheric stability conditions.
30. True or False? Temporary  $PM_{10}$  monitoring stations are most effective when they are used in conjunction with modeling results to confirm or deny the influence of specific sources on  $PM_{10}$  air quality levels.
31. Mobile  $PM_{10}$  monitoring can be used to \_\_\_\_\_.
- identify  $PM_{10}$  concentration peaks downwind of large elevated point sources
  - determine upwind and downwind  $PM_{10}$  concentrations resulting from sources of ground-level fugitive emissions
  - a and b, above
  - none of the above
32. Which of the following is (are) useful in documenting a  $PM_{10}$  monitoring site?
- exposure diagram for the  $PM_{10}$  sampler
  - list of all  $PM_{10}$  point and area sources within 1.5 kilometers of the sampler
  - list of all major  $PM_{10}$  point sources within 8 kilometers of the sampler
  - a and b, above
  - all of the above

# Review Exercise Answers

|                | <b>Page*</b> |
|----------------|--------------|
| 1. e.....      | 44-47        |
| 2. d .....     | 47           |
| 3. c.....      | 48           |
| 4. f.....      | 48           |
| 5. True.....   | 49           |
| 6. True.....   | 53           |
| 7. False.....  | 54           |
| 8. True.....   | 53           |
| 9. d .....     | 54           |
| 10. False..... | 55           |
| 11. f.....     | 56           |
| 12. True.....  | 57           |
| 13. e.....     | 57           |
| 14. True.....  | 57           |
| 15. False..... | 69           |
| 16. c.....     | 64-67        |
| 17. c.....     | 67           |
| 18. d .....    | 67           |
| 19. a.....     | 74-76        |
| 20. a.....     | 69           |
| 21. b .....    | 69           |
| 22. c.....     | 69           |

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\* Refer to pages 44-100 of EPA-450/4-87-009 *Network Design and Optimum Site Exposure Criteria for Particulate Matter*.

|                |    |
|----------------|----|
| 23. d .....    | 81 |
| 24. c .....    | 81 |
| 25. d .....    | 81 |
| 26. d .....    | 81 |
| 27. c .....    | 77 |
| 28. True ..... | 77 |
| 29. True ..... | 77 |
| 30. True ..... | 85 |
| 31. c .....    | 86 |
| 32. e .....    | 87 |



## SECTION 5

### SITE SELECTION METHODOLOGY

The general procedure recommended for selecting sites for monitoring PM<sub>10</sub> is similar to that followed for monitoring any pollutant. Variations are recommended primarily with regard to specific methodologies or data that are needed for different topographical situations or different configurations of emissions. Procedures are discussed and recommendations are given for treating the six representative siting situations identified for PM<sub>10</sub> in Section 4.

#### OVERVIEW OF METHODOLOGY

The siting of monitors is part of a continuing planning cycle for monitoring, which goes on in all air pollution control agencies and operating facilities. The three basic elements of the cycle, as shown in Figure 14, include defining the objective of monitoring, collecting monitoring data, making judgments about air quality levels. The methodology for selecting monitoring sites is designed with the idea that this is part of an iterative process that has been performed before and will be repeated again in the future. The need for flexibility in the use of monitoring resources was clearly recognized by the Standing Air Monitoring Working Group (EPA 1977). This need has resulted in the development of three types of monitoring activities by state and local agencies, including National Air Monitoring Stations (NAMS), State and Local Air Monitoring Stations (SLAMS), and Special Purpose Monitoring (SPM). The locations of NAMS and SLAMS must be coordinated with EPA regional offices because these must be designed to meet EPA needs in addition to state and local needs. The siting methodology is applicable to all three types of monitoring stations and will be useful to industrial operating facilities as well as air pollution control agencies.

The general site selection process is illustrated in Figure 15. The procedure is applicable to all PM<sub>10</sub> siting requirements, although the indicated steps may be considerably simpler for some types of monitoring requirements than for others. Each box shown in the diagram defines a data review and analysis step. The diamonds define decisions, and the rounded boxes define data needs. The process is divided into the following six steps, which are performed in sequence:

1. Analyze existing PM monitoring data
2. Review local situation to determine adequacy of mapping analysis and/or to select a modeling procedure
3. Model air quality scene (if necessary)
4. Determine network requirements

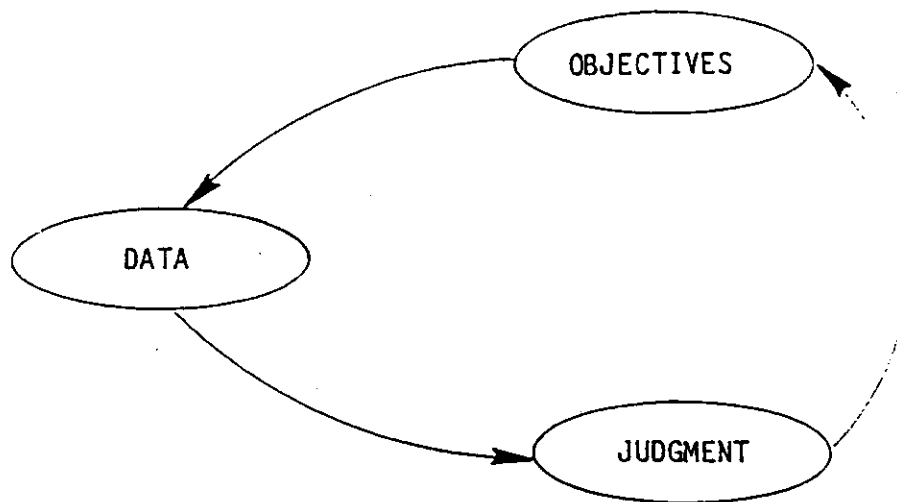


Figure 14. Planning cycle for monitoring.

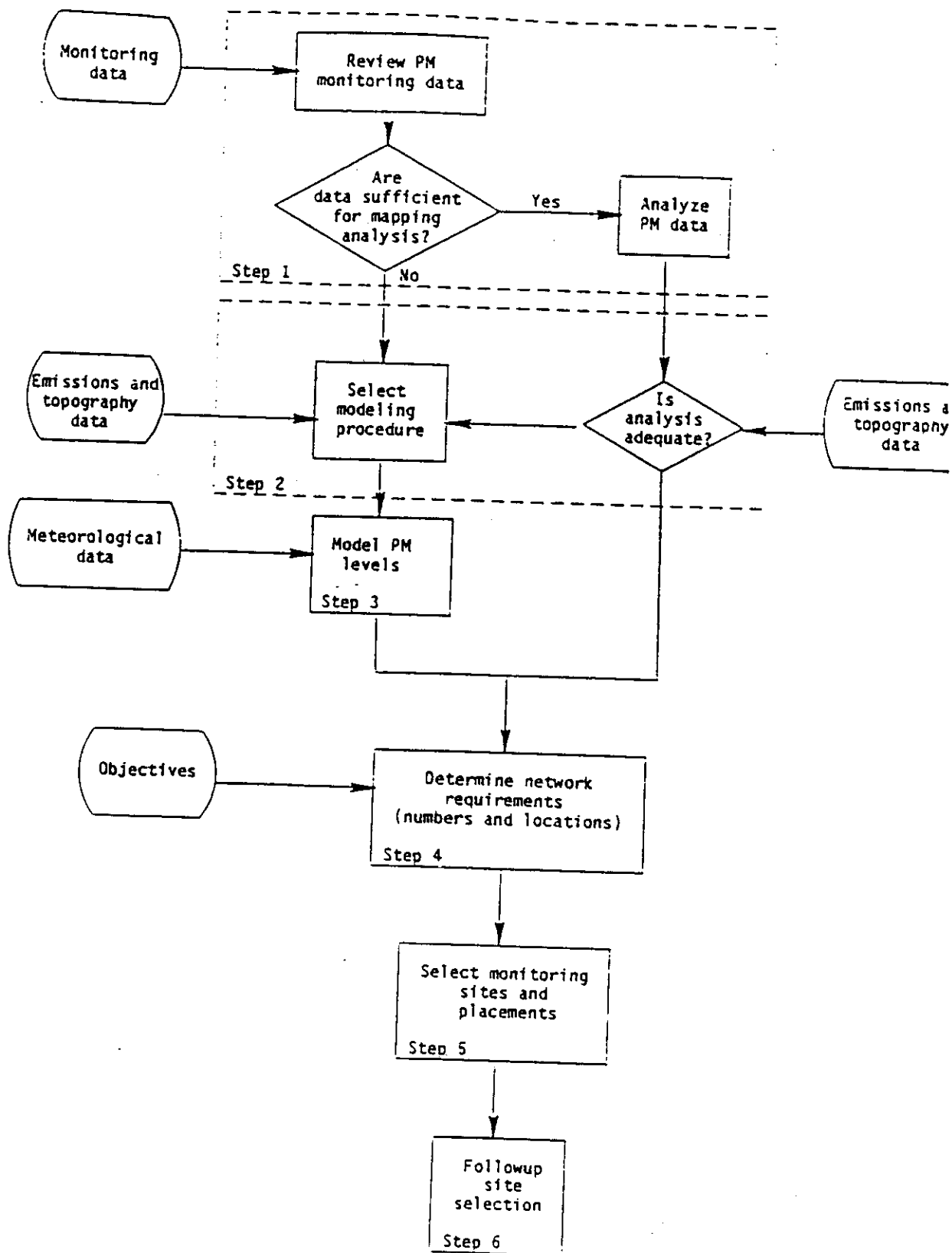


Figure 15. Procedure for selecting PM<sub>10</sub> monitoring sites.

- 5. Determine monitoring sites and placement
- 6. Document and update site exposure experience.

Site planning may vary in scope of responsibility and may include any of the following:

- Design multipurpose network
- Supplement existing network for specific purpose
- Design single-source impact or compliance monitoring network
- Monitor a designated area or location.

Guidelines for performing each step in the site selection process and variations that deal specifically with each of the six types of siting situations are described in the subsequent subsections.

#### ANALYZE EXISTING AMBIENT PM MONITORING DATA

In order to devise a monitoring strategy and select monitoring sites, the monitoring planner must hypothesize the historical spatial distribution of PM<sub>10</sub> concentrations over the area of concern. An adequate data base of related measurements, such as for TSP matter, may be available to meet this need. If not, the distribution must be estimated by mathematical simulation modeling or by a reasonable, physically based qualitative analysis. The best method of estimating the distribution of air quality levels will depend on the amount, type, and quality of available information. The information of interest includes the following categories:

- Suspended particulate matter measurements
- Locations and amounts of particulate emissions
- Air pollution climatology and meteorology data
- Maps of topographical features.

As a general rule, the amount of monitoring data available to help design a monitoring network or site new monitors is either nonexistent or very incomplete. However, with regard to siting new PM<sub>10</sub> monitors, there is likely to be a wealth of hi-vol monitoring data for TSP concentrations that can be very helpful. Other relevant ambient PM measurements include IP measurements, tape sampler measurements, and various types of direct and

indirect PM measurements. The EPA SAROAD data base, available from EPA regional offices, is a convenient source of much of the available data. State and local air pollution control offices are also important sources of additional data and information about other data that may have been collected by nongovernment parties or in special studies.

After assembly of all available data and elimination of data that are suspect because of poor quality control, a decision is made as to whether the available data is sufficiently dense to justify mapping analysis, or whether single-station analysis is more valuable. Generally, unless measurements are available from at least six sites concurrently, mapping analysis is not practical.

### Mapping Analysis

When performing mapping analyses, different types of measurement data should not be mixed on the same map unless an adequate calibration correction is made for different types of data. If corrections are to be made, it would be convenient if the different types of measurements were corrected to estimates of PM<sub>10</sub> concentrations. As a minimum, two types of maps should be constructed, including one for annual means and one for peak 24-hour concentrations (not concurrent) for each year of data, particularly the most recent years. In addition, it will be useful to plot concurrent 24-hour data for a few days that are distinguished by having one or more high values. The maps may be constructed by locating the observing sites on a convenient mapping display. The appropriate values may be entered at each site to provide a guide for drawing a set of representative contours of concentrations. The number and value of contours to be drawn will depend on the range of values observed and the nature of their spatial distribution. Computer graphics packages are available to perform the contouring analysis if manual analysis is not practical. Generally, about six contours will provide a useful display. However, as few as one or as many as 10 may be appropriate, depending on the magnitude of the range relative to the mean of the values observed. The maps will be used to identify representative spatial scales and preliminary siting selections.

While the mapping and station analysis data may be helpful in identifying the spatial distribution of PM<sub>10</sub>, they may be inadequate. Having analyzed the available data, the monitoring planner must consider whether modeling is needed to supplement the available monitoring data. Consideration should be given to gradients evident in the observations, locations of major sources, terrain, and meteorology. In most cases the available PM observations will not be adequate for planning a new monitoring network.

### Single-Station Analysis

When single-station analyses are performed, it is desirable to identify the significant influencing factors that affect the PM<sub>10</sub> air quality levels observed. This identification process will help determine how wide an area

the station represents. Conclusions drawn from one station should be compared with results from other stations in the area of interest. Trends and frequency distributions help in analyzing single-station data. Case study analyses of peak values will also be helpful. Figure 16 shows an example of 12-month running means for three sites in Youngstown, Ohio. When significant trends exist, they may indicate the influence of a nearby source. This would be especially true if trends at one site are more pronounced than at other sites. The down trends at the three Youngstown stations might be attributed to decreasing steel production in the local area. The differences among the stations might be attributed to the locations of sites relative to steel production areas and the prevailing wind directions. Shorter averaging periods, such as 3-month averages, would be helpful in identifying seasonal variations that might be associated with specific sources or meteorological conditions.

An example of statistical analysis of single-station data is presented in Table 9. Locations that have similar frequency distributions, particularly over a period of several years, can be considered to be in homogeneous areas. To further support the identification of homogeneous areas, it is useful to review meteorological conditions associated with a selected range of high values. Because TSP measurements represent 24-hour values, a good deal of care is required in selecting meaningful meteorological values. The prevailing (most frequent) and the range of wind directions corresponding to the measurement period are useful. Wind persistence (ratio of vector mean to scalar mean wind speed), height and magnitude of nocturnal temperature inversion, scalar average wind speed, and range of Pasquill stability categories (see definition in Turner 1970) are other meteorological parameters that may show consistent values with the high TSP measurements. If the meteorological conditions associated with high measurements differ significantly between monitoring sites, this result indicates that the sites represent different zones of air quality and has an important bearing in planning a monitoring network.

Another useful single-station analysis is the pollution rose. Figure 17 shows pollution roses constructed for four sites near a coking plant. The pollution rose is constructed by computing the average measured concentration for all values when the prevailing wind was in a given direction. The values may be limited to days when the wind persistence index (ratios of vector to scalar wind speed) exceeds a certain value. In Figure 17, the data include only days with a wind persistence index equal to or greater than 0.85.

#### REVIEW OF LOCAL SITUATION

An important step in the process of selecting monitoring sites is to identify the unique local influences that are affecting air quality. The types of topographical features, the magnitudes of PM emissions, and the locations of both with respect to one another have a major impact on where the worst air quality levels will occur. In assessing the value of available monitoring data and in selecting an air quality simulation model, it is necessary to take these local influences into account. After a brief

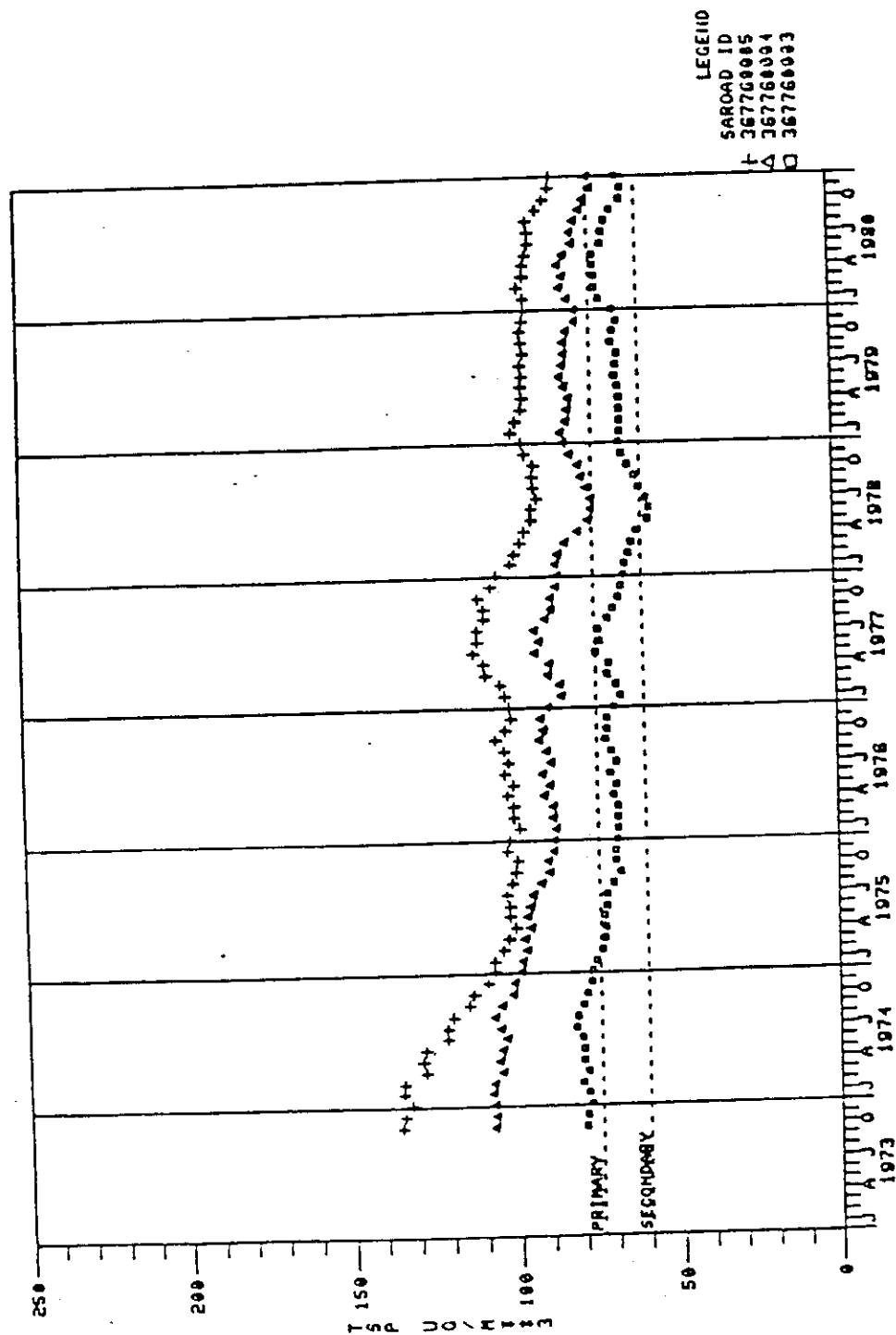


Figure 16. Twelve-month running geometric means (Pickerling, Villardo, and Rector 1981).

TABLE 9. TSP DATA SUMMARY FOR SAROAD STATION #391720001  
(Units in micrograms/m<sup>3</sup>) (Pickering, Villardo, and Rector 1981)

| YEAR                             | 1973            | 1974            | 1975            | 1976            | 1977            | 1978            | 1979            | 1980            |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| # OF READINGS :                  | 59              | 81              | 95              | 109             | 113             | 110             | 113             | 79              |
| GEOMETRIC MEAN:                  | 122.5           | 114.9           | 109.2           | 90.2            | 99.2            | 95.9            | 90.0            | 93.1            |
| GEOMETRIC S.D.:                  | 1.8             | 1.6             | 1.6             | 1.5             | 1.7             | 1.7             | 1.5             | 1.5             |
| HIGHEST BY<br>LARSEN EXTRP:      | 635.4           | 460.4           | 406.4           | 326.1           | 440.3           | 431.4           | 299.5           | 319.5           |
| 1ST HIGHEST:<br>DATE :           | 495.0<br>730415 | 295.0<br>740117 | 314.0<br>750419 | 259.0<br>760915 | 275.0<br>770310 | 369.0<br>780426 | 273.0<br>790322 | 355.0<br>800537 |
| 2ND HIGHEST:<br>DATE :           | 339.0<br>730425 | 281.0<br>740905 | 277.0<br>750924 | 204.0<br>760924 | 231.0<br>771105 | 237.0<br>781122 | 225.0<br>791123 | 194.0<br>800907 |
| # OF READINGS<br>EXCEEDING 250 : | 4               | 4               | 3               | 0               | 1               | 1               | 1               | 1               |
| # OF READINGS<br>EXCEEDING 150 : | 24              | 20              | 22              | 17              | 27              | 19              | 8               | 10              |
| RANGE                            |                 |                 |                 |                 |                 |                 |                 |                 |
| 0-55:                            | 9               | 11              | 15              | 29              | 25              | 27              | 36              | 16              |
| 56-130:                          | 20              | 37              | 48              | 54              | 49              | 48              | 52              | 46              |
| 131-195:                         | 20              | 22              | 20              | 23              | 32              | 27              | 11              | 16              |
| 196-250:                         | 5               | 7               | 9               | 3               | 5               | 7               | 3               | 0               |
| 251-325:                         | 2               | 4               | 3               | 0               | 1               | 0               | 1               | 0               |
| 326-390:                         | 1               | 0               | 0               | 0               | 0               | 1               | 0               | 1               |
| 391-455:                         | 0               | 0               | 0               | 0               | 0               | 0               | 0               | 0               |
| >455:                            | 1               | 0               | 0               | 0               | 0               | 0               | 0               | 0               |



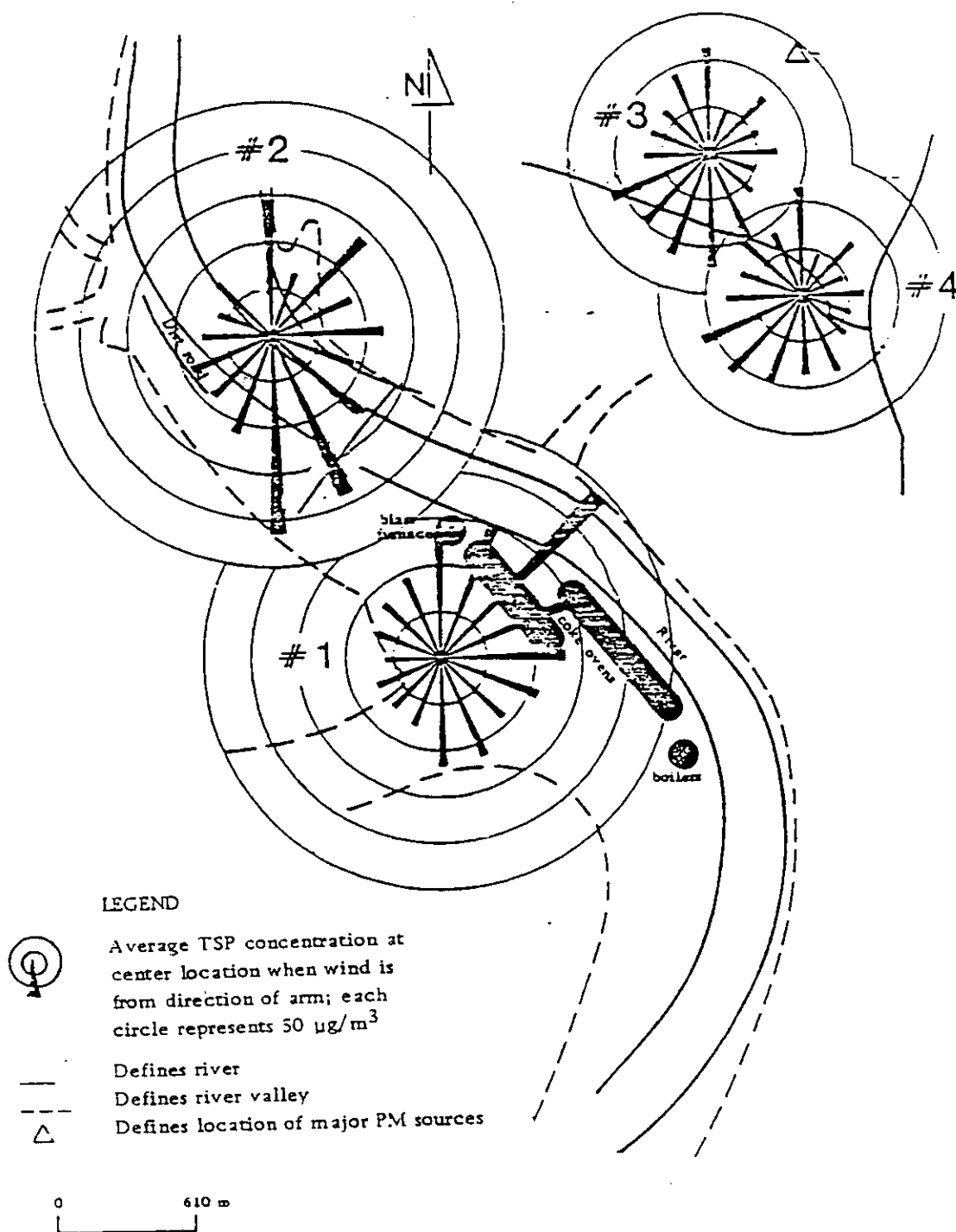


Figure 17. TSP roses for four sites near a coking plant (Pickering, Vilardo, and Rector 1981).

description of the information needed, suggestions are given for steps to take in evaluating available air quality and for estimating PM<sub>10</sub> air quality levels by the use of mathematical models.

#### Emission Data

X  
#4  
Information on the locations and magnitudes of sources of particulate matter emissions is needed. The influence of PM<sub>10</sub> sources can be determined by the use of air quality dispersion models and graphical aides that treat the contributions of sources to receptor locations, and by qualitative interpretation of the model results in the light of known topographic influences and monitoring data. Available sources of data and how they may be used in monitor siting analysis is provided here.

Two useful items of information are a detailed and accurate land use map and an accurate point source emission inventory. Large-area, statewide, or multistate maps are needed to show the locations of major population and industrial areas. Smaller area maps that show the size and location of different types of urban development within a single city are also needed for most monitoring objectives. There are many sources for the large-area maps. City-size land use maps are usually available from city and county planning offices. U.S. Geological Survey maps or Sanborn maps may be useful if other sources of land use maps are not available. Another very useful source of data on land use is the U.S. Geological Survey's records of aerial photographic coverage and space imagery. Reference files of data available on microfilm are maintained at the EROS Data Center of the U.S. Geological Survey in Sioux Falls, South Dakota. (See Appendix B for recommended contacts.)

Detailed information on specific sources of particulate emissions is available in state and local emission inventories. Both area and point source emission data are needed. Area source emissions are typically estimated on a countywide basis. However, estimates are frequently allocated to a fine grid in order to provide inputs to dispersion models or for other purposes. Gridded area source data that include location, emission rate, and stack parameters (e.g., temperature and volume flow rate) are needed. When accurate and complete, the NEDS data available from EPA include peak and average emission rates and seasonal variations in addition to the minimum information on location and emissions.

In addition to the emission inventory, census data and traffic data may be used to help define the spatial distribution of particulate emissions, particularly emissions associated with fuel combustion for space heating and emissions from vehicle kickup and tailpipe exhaust. If seasonal variations of emissions due to space heating are not available, they can be estimated on a seasonal or daily basis by use of degree days.<sup>1</sup>

<sup>1</sup> A degree day is the amount that the average of the daily maximum and minimum temperatures is less than 65° F. Days on which the average is 65° F or greater are not counted.

Emission data for particulate matter are most complete and most accurate for stack emissions from large point sources. However, the principal sources of PM<sub>10</sub> concentrations are fugitive emissions, secondary particles, and emissions from automobile exhaust (Watson, Chow, and Shah 1981). Special attention is needed to ensure that the emission inventory is reasonably accurate with respect to industrial material handling operations, fumes from uncontained processes, mechanically reentrained road dust (both paved and unpaved roads), and windblown dust from disturbed soil, or a variety of industrial sources (Pace 1980).

### Topography

The topography of an area will affect the transport and dispersion of pollutants released to the atmosphere. It is important to take note of topographical features in evaluating how adequately monitoring data represent the expected air quality levels and in selecting a modeling approach for simulating air quality levels. The following topographical features are of interest:

- Shorelines of major bodies of water
- Boundaries of significant urban areas (primarily covered by buildings and pavement)
- Significant terrain elevation features, including ridges, valleys, and areas of complex terrain.

The influence of topography on atmospheric transport is discussed in Section 4. The location of air monitoring sites in relation to sources of PM emissions must be reviewed in the light of these influences. An air pollution meteorologist may be consulted regarding the significance of topographical effects, if there is a doubt about the effect.

The locations of these features are easily identified on topographical maps available from the U.S. Geological Survey.

### Reviewing Local Effects

Having assembled data that describe the local situation with regard to measurements of air quality, sources of emissions, meteorology, and terrain, the monitoring site planner is ready to assess the nature of these influences and determine whether to use modeling or qualitative analysis for assistance in selecting monitoring sites.

With regard to sources of particulate emissions, it is necessary to identify the locations of major sources and the quantity of emissions emanating both from stacks and as fugitive dust. Smaller sources of particulate emissions may be represented as area sources, e.g., as emission densities over 1 km squares. The area source emission densities should include particulate emissions from fuel combustion by smaller commercial and industrial sources, by residences, and by all types of mobile sources; also, process and fugitive dust emissions from industrial, waste disposal, and construction operations should be included. Guidelines on how to conduct an emission inventory and to allocate emission data to a gridwork are available from EPA (1973) and are not documented here. Both annual mean and seasonal, monthly, or daily maximum (if they are significantly different from the annual) emission rates should be determined. When plotted on maps, the area emission densities (both mean and maximum) will indicate areas of relative maximum and minimum emission levels and the degree of homogeneity in the area source emissions over the monitoring area of interest.

The nature of major topographical features and their locations relative to the sources of particulate emissions need to be identified. Major topographical features include coastlines, ridge lines, valley walls, and hilltops. In addition to specific topographical features, the area may be generally characterized by its roughness, e.g., built-up urban area, moderately rough rolling hills or river valley, or extremely rough valleys and ridges of a mountainous area. The treatment of terrain roughness is further complicated by the need to deal with terrain transitions. Cities and other areas of interest are frequently located near the base of a mountainous area or on a coastline where major terrain transitions exist.

While the location and nature of terrain features help to identify their influence, meteorological data are the demonstrated evidence of the effect. All of the air quality models recommended in the EPA Guideline on Air Quality Models (Revised) (1986) assume that meteorological conditions are homogeneous between all combinations of sources and receptors. Therefore, the available meteorological data should be reviewed to delineate areas and time for which the homogeneity assumption and the recommended models are applicable.

The single most significant meteorological parameter that must be homogeneous is wind direction. Since wind direction at a single site is generally accurate within 10° azimuth,<sup>2</sup> the variance in wind direction differences between sites should not exceed the sum of that variance due to measurement errors at the two sites. A useful rule of thumb is that the standard deviation of the differences in wind direction at two sites should not exceed  $\sqrt{2}$  times 10°, or be less 15°, if the two sites are assumed to be measuring the same wind direction.

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<sup>2</sup>This is related to the spatial representativeness of the observations and not the accuracy of the wind vane.

If meteorological data are not available to demonstrate the homogeneity of meteorological conditions, one can require that there be no major topographical features between sources of pollution and potential receptor monitoring sites in areas selected for modeling analysis. While this may be helpful in the immediate area, it does not treat indirect effects in nearby areas due to wind flow away from major topographical features. Lake breeze fronts and valley drainage flow fronts are examples of air boundaries that lie away from the topographical features that generate them. Winds on opposite sides of these air boundaries may differ by  $90^\circ$  or more, and the boundary may lie several miles away from the terrain feature. Air quality models that treat the effects of these terrain-generated air boundaries are under development and evaluation. One important effect of these boundaries, namely limited vertical mixing, can be treated by the available models.

#### Is the Analysis of Monitoring Data Sufficient?

The patterns and directions of maximum levels may differ for long- and short-term  $PM_{10}$  concentrations. Both types of patterns should be reviewed separately. The important judgment to be made is whether the effects shown by the monitoring data are reasonable in the light of other available information, or whether modeling is needed to better define the spatial pattern of  $PM_{10}$  concentrations.

In order to be useful for siting purposes, the monitoring data should define the shape and magnitude of the air quality pattern. Based on the distribution of sources, topography, and meteorology, the pattern should reflect these influences or at least not be inconsistent with respect to them. If these expectations are met, one may accept the pattern shown by the monitoring data as adequate. If the expectations are not met, a more detailed analysis based on results from air quality simulation models or from supplementary mobile monitoring may be required. There are two types of comparisons that can be made to help judge whether the air quality patterns are acceptable. One comparison examines the time history of the pattern. The other comparison examines the shape of the air quality pattern with respect to the shape of the pattern of emission densities and topographical features.

If the patterns of annual means or maximum 24-hour concentrations for several years show the same shape and same locations of peaks when superimposed on each other, the pattern is consistent with time. This consistency is evidence of a stable pattern, which is a reasonable guide for planning monitoring sites. If the pattern is changing with time, the analysis may be adequate, but the reasons for the changing pattern should make sense in terms of changes in sources or in meteorological conditions. If there are no apparent reasons for the changes, modeling results should be obtained and reviewed.

Emission densities that are chronologically consistent with the air quality data should be plotted and used to generate contour patterns. Topographical features may also be located on these patterns. When the emission density contours are superimposed on the air quality patterns, then

should be a reasonable relationship. One possible cause of deviations might be due to significant amounts of emissions from stacks. The heights of the stacks should be noted as an aid in identifying this influence. As a general rule, most IP and TSP emissions are from ground-level sources; however, uncontrolled or undercontrolled emissions from stacks can be major sources of pollution, which significantly alters the pattern of air quality from what would be observed from ground-level sources. A reasonably consistent pattern would be one in which the air quality pattern is offset from the emission pattern in the direction of prevailing wind flow. If the influence of major peaks in emission density are not evident in the air quality pattern, a modeling analysis may be helpful in identifying the magnitude of the pattern deformation that can be expected.

### Selecting a Model

Major unsolved problems are associated with modeling PM concentrations. When using the results of model simulations to select monitoring sites, one should keep the following uncertainties in mind:

- Most of the IP matter that makes up the concentrations occurring in urban locations may not originate from local sources.
- Air quality simulation models recommended in the Guideline (EPA 1986) do not treat the physical and chemical processes that alter the size of airborne particles and may not adequately treat their removal by wet and/or dry deposition.
- Emission factors and emission data that are available to estimate emissions of particulate matter do not identify IP emissions as a portion of total PM emissions.
- Most IP emissions originate from fugitive sources rather than stacks. The uncertainty associated with available fugitive emission estimates is very high.
- Air quality simulation models recommended in the Guideline (EPA 1986) very simplistically treat the topographical influences on atmospheric transport and dispersion of pollutants.

In spite of these uncertainties it is still useful to use modeling to identify areas of relatively good and poor air quality and to select sites for a monitoring network. Models that may be useful in each of the six monitoring situations described at the end of Section 4 are listed in Table 10. No modeling results are needed to site a regional scale monitoring station, because this type of site is representative of a large, relatively homogeneous area of air quality in which influences from nearby sources are

TABLE 10. AVAILABLE EPA MODELS FOR SIX MONITORING SITUATIONS\*

| Monitoring Situation  | Recommended model         |                   |
|---|---------------------------|-------------------|
|   | Annual Mean               | Maximum 24-h      |
| Regional scale  | None**                    | None**            |
| General urban area  |                           |                   |
| -- uniform  | CDM-2.0                   | RAM               |
| -- for complex sources in urban areas                               | ISC                       | ISC               |
| Urban area with single or multiple major IP source(s)               | CDM-2.0                   | RAM               |
| Single source with terrain height below stack top# (complex source) | CRSTER                    | CRSTER            |
| Single source near terrain above stack top§                         | COMPLEX I***<br>or VALLEY | VALLEY<br>COMPLEX |

\* Available on EPA's UNAMAP Version 6.

# For multiple sources where it is not appropriate to consider the emissions as located at a single point, the MPTER model is appropriate.

§ COMPLEX I and VALLEY are considered screening techniques. For regulatory purposes, COMPLEX I should be used only with onsite meteorological data as input.

\*\* Selection of model is a case-by-case decision.

\*\*\* The SHORTZ model is an appropriate screening technique for use in urbanized valleys with onsite meteorological data as input.

negligible. With regard to selecting a model, a distinction is made between monitoring situations with a single source in a rural setting and monitoring situations with multiple sources in an urban setting. A distinction is also made between rural monitoring situations with and without complex terrain. For modeling purposes, complex terrain is usually defined as terrain that exceeds the stack top of the source.

For estimating annual means, the CDM model is appropriate for multiple source urban situations, and the CRSTER model is recommended for single-source rural situations in the absence of complex terrain. In the presence of complex terrain, the COMPLEX I screening model for rural areas and the SHORTZ screening model for urban areas (available in the EPA UNAMAP Program System, Version 6) are more appropriate than VALLEY, if at least 1 year of onsite meteorological data are available. These models are relatively easy and inexpensive to use. For estimating maximum 24-hour concentrations, the RAM model is recommended for urban situations and CRSTER for single-source, rural situations. When the single source or multiple major IP sources are complex (as is frequently the case when treating fugitive emissions from large industrial sources), the ISC model is recommended in place of RAM or CRSTER.

Procedures for using these models and for compiling data for them are discussed in detail in the Guideline on Air Quality Models (Revised) (EPA 1986), and the PM<sub>10</sub> SIP Guideline. In addition, Appendix A contains a list of cities for which STAR data have been compiled. These data should be helpful to modelers who wish to execute CDM or ISCLT. Appendix B contains a list of information sources that should also prove helpful.

#### Selecting Representative Sites Without Monitoring or Modeling Data

There may be situations in which it is not possible to use monitoring data or the results of a modeling analysis to define the pattern of air quality levels in an area that is to be monitored. In this case, the monitoring network can be planned by identifying representative sites on the basis of available information on sources of emissions, climatological data, and topographical considerations. Section 4 presents a discussion of how these physical characteristics of the area to be monitored influence the air quality with respect to PM<sub>10</sub>. On the basis of these considerations, six representative monitoring situations were identified. Observations from other locations and previous modeling analyses of general classes of source influences may be used to select PM<sub>10</sub> monitoring sites for these situations.

Figures 18 through 21 summarize the steps that need to be followed in selecting sites for the six types of representative monitoring situations. Figure 18 treats regional scale siting. Figure 19 treats siting neighborhood-scale sites in urban areas, and Figure 20 treats siting middle scale sites with and without the presence of major point sources. These two figures cover the three urban representative siting situations identified in Section 4. Figure 21 treats siting around an isolated major point source in flat or



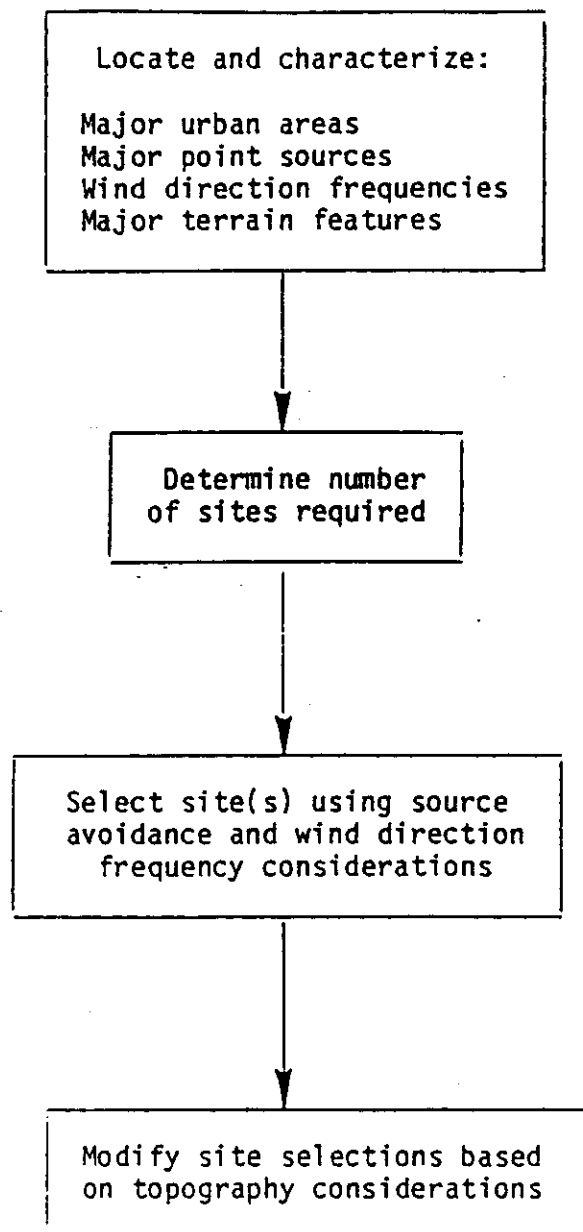


Figure 18. Steps for locating regional scale monitoring site.

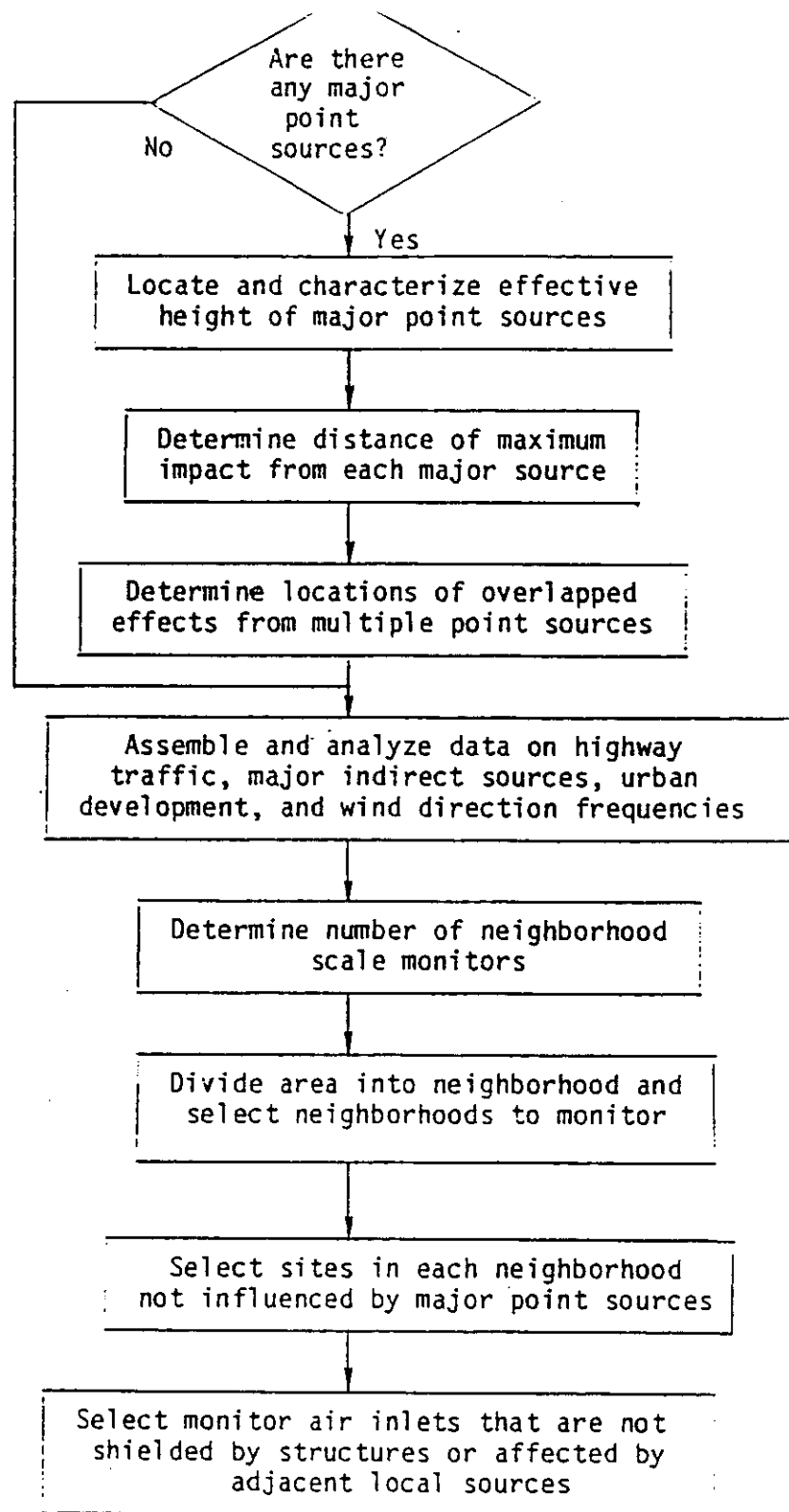


Figure 19. Steps for locating a neighborhood scale monitoring site in an urban ar

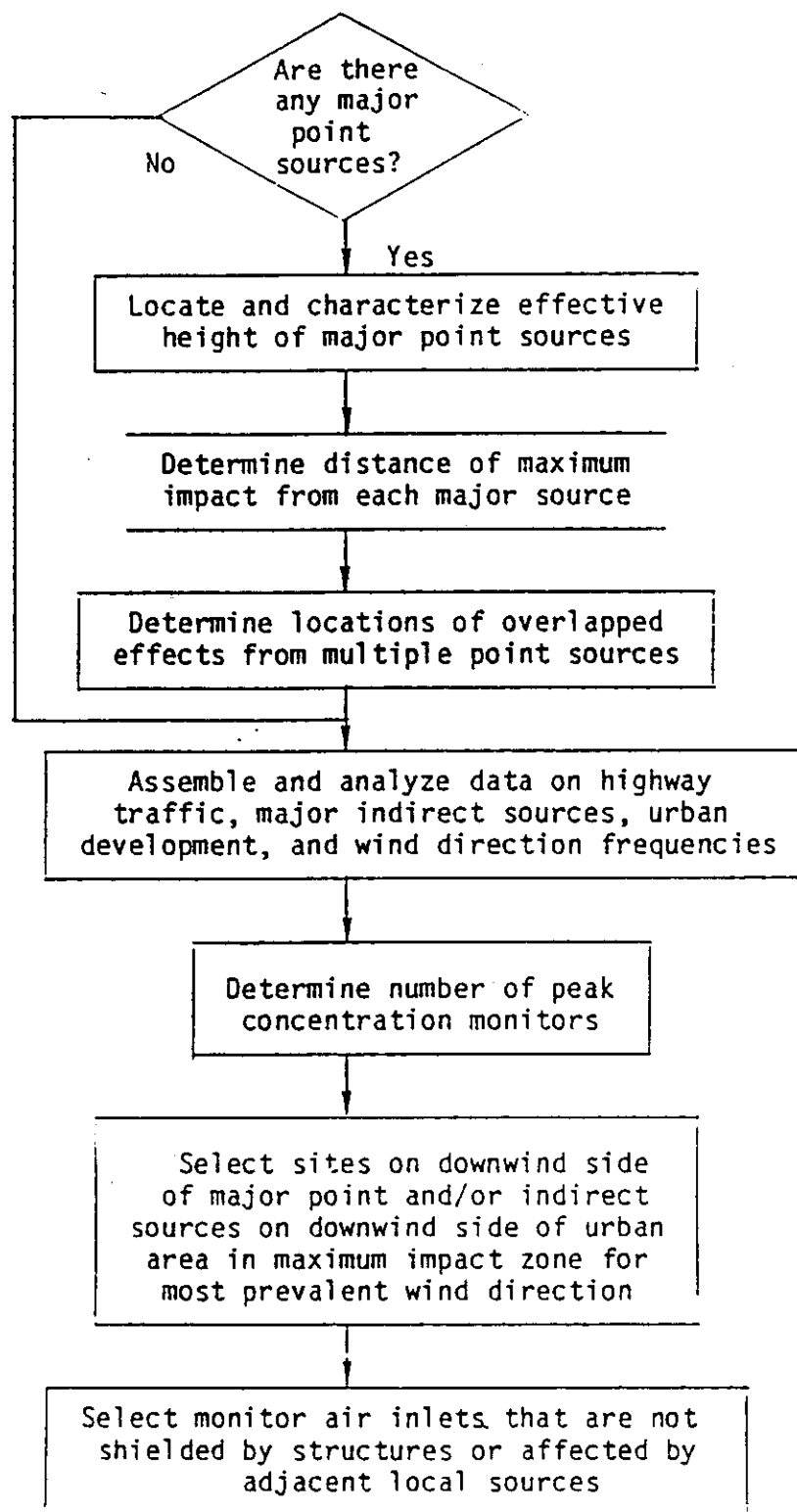


Figure 20. Steps for locating micro-/middle scale monitoring sites in urban

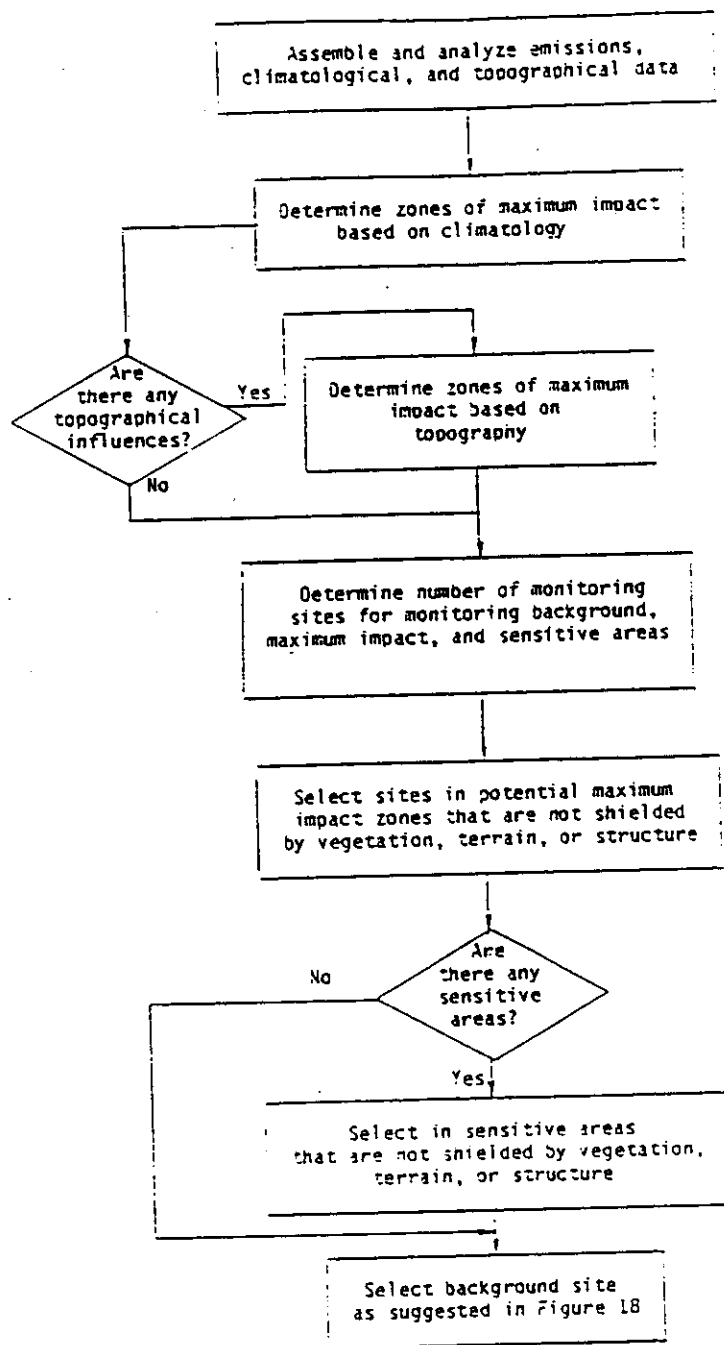


Figure 21. Steps for locating monitoring sites near isolated major sources.

complex terrain. This includes two of the representative siting situations. These three figures deal with all six representative siting situations. Specific guidelines that may be used in performing these steps are discussed below.

### Regional Scale Monitoring Sites

Regional scale monitoring sites are needed to measure background levels of  $PM_{10}$  that are transported into the area being monitored. It is important that regional scale monitoring sites not be affected by nearby sources, which would significantly alter their scales of representativeness, for large periods of time. It may be necessary to use two or more sites to measure background concentrations when a single site cannot be found that is never influenced by nearby sources. Figure 18 suggests four steps to follow in selecting the site(s).

The first step is to identify all major urban areas and all major operating facilities that may have an effect on  $PM_{10}$  air quality levels in the area of concern. Locations and populations of nearby urban areas are readily determined from maps and standard library references. Large cities as far away as 100 km are of concern. This is based on the use of models to estimate the distance to which emissions of  $1.0 \mu g/m^2/sec$  from a metropolitan area 40 km in diameter will extend before the peak concentration is less than  $20 \mu g/m^3$  under neutral atmospheric stability conditions and a light wind speed of 2 m/sec. Distances from smaller cities are less critical; e.g., a concentration of  $20 \mu g/m^3$  will extend 60 km downwind of a city that is 20 km in diameter and 15 km downwind of a city that is 10 km in diameter. These estimates were derived using the methodology for Estimation of Concentrations from Area Sources proposed by D.B. Turner (1974). A concentration of  $20 \mu g/m^3$  is significant because this is the 1-hour concentration that is likely to be associated with an observed 24-hour concentration of  $5 \mu g/m^3$ , and because 24-hour concentrations as low as  $5 \mu g/m^3$  are small in comparison to observed variations in regional scale IP concentrations. Annual mean concentrations of IP at 17 monitoring sites in nonurban areas (Watson, Chow, and Shah 1981) showed a mean of  $30 \mu g/m^3$  and a standard deviation of  $9 \mu g/m^3$ . A concentration of  $5 \mu g/m^3$  is about half of the standard deviation of regional scale or background level concentrations of IP.

Major operating facilities can be identified from state emission inventories that are available from state and Federal offices listed in Appendix. Estimates of significant impact distances are listed in Table 11 for various emission rates and effective source heights. Effective source height refers to the height above the ground at which the center of the plume of emissions from a plant is transported. This includes the height of release from a stack or vent plus the rise that may occur due to momentum and/or heat in the exhaust stream. For fugitive emissions blown from the ground or vented from open windows and doors, the effective height may be essentially zero or ground level. All areas affected by major sources can be circled on

a map by a radius scaled to the significant impact distance. The circles should include the urban area and major sources in the area being monitored as well as nearby sources outside of the area. Any areas not covered by circles are suitable for regional-scale monitoring sites. Sites within 40 m of major highways (see Figure 22) or unpaved roads are also not suitable. This is because emissions from motor vehicles in heavy traffic and the reentrainment of dust from unpaved roads are also significant sources of particulate matter. If there are no uncovered areas or if the uncovered areas are unsuitable because of accessibility or other considerations, it is necessary to use more than one site to monitor the regional scale. Operations from different sites would be applicable to background levels on different days.

TABLE 11. DISTANCES FROM MAJOR POINT THAT AFFECT REGIONAL SCALE MONITORS

| Emissions rate (g/sec) | Effective source height (m) | Downwind distance (km) beyond which the product of concentrations and wind speed does not exceed $40 \mu\text{g}/\text{m}^3 \times \text{m}/\text{sec}$ for four Pasquill stability classes |     |      |      |
|------------------------|-----------------------------|---|-----|------|------|
|                        |                             | B   | C   | D    | E    |
| 400                    | all                         | 14  | 30  | >100 | >100 |
| 100                    | 300                         | 7   | 14  | 33   | --*  |
|                        | <150                        | 7   | 14  | 50   | >100 |
| 40                     | 300                         | 4.5   | 7   | --   | --   |
|                        | 100                         | 4.5   | 8   | 25   | 50   |
|                        | <70                         | 4.5   | 8   | 27   | 57   |
| 10                     | >300                        | --  | --  | --   | --   |
|                        | 100                         | 2.1   | 4   | 8    | 11   |
|                        | <30                         | 2.1   | 4   | 10   | 19   |
| 4                      | 100                         | 1.2   | 2.0 | --   | --   |
|                        | <30                         | 1.4   | 2.4 | 5    | 9    |

\* Dashes indicate values as high as  $40 \mu\text{g}/\text{m}^2/\text{sec}$  do not occur.

NOTE:  $40 \mu\text{g}/\text{m}^2/\text{sec}$  represents the lowest value that is expected to produce a 24-hour concentration contribution of at least  $5 \mu\text{g}/\text{m}^3$ . This is based on the assumptions that a 24-hour value will be about 25 percent of the 1-hour peak concentration and that wind speed will be 2 m/sec. A concentration contribution of  $5 \mu\text{g}/\text{m}^3$  is small in comparison to variations in regional scale IP concentrations (see text). Tabulated values are based on curves from the EPA Workbook of Atmospheric Dispersion Estimates (Turner 1970).

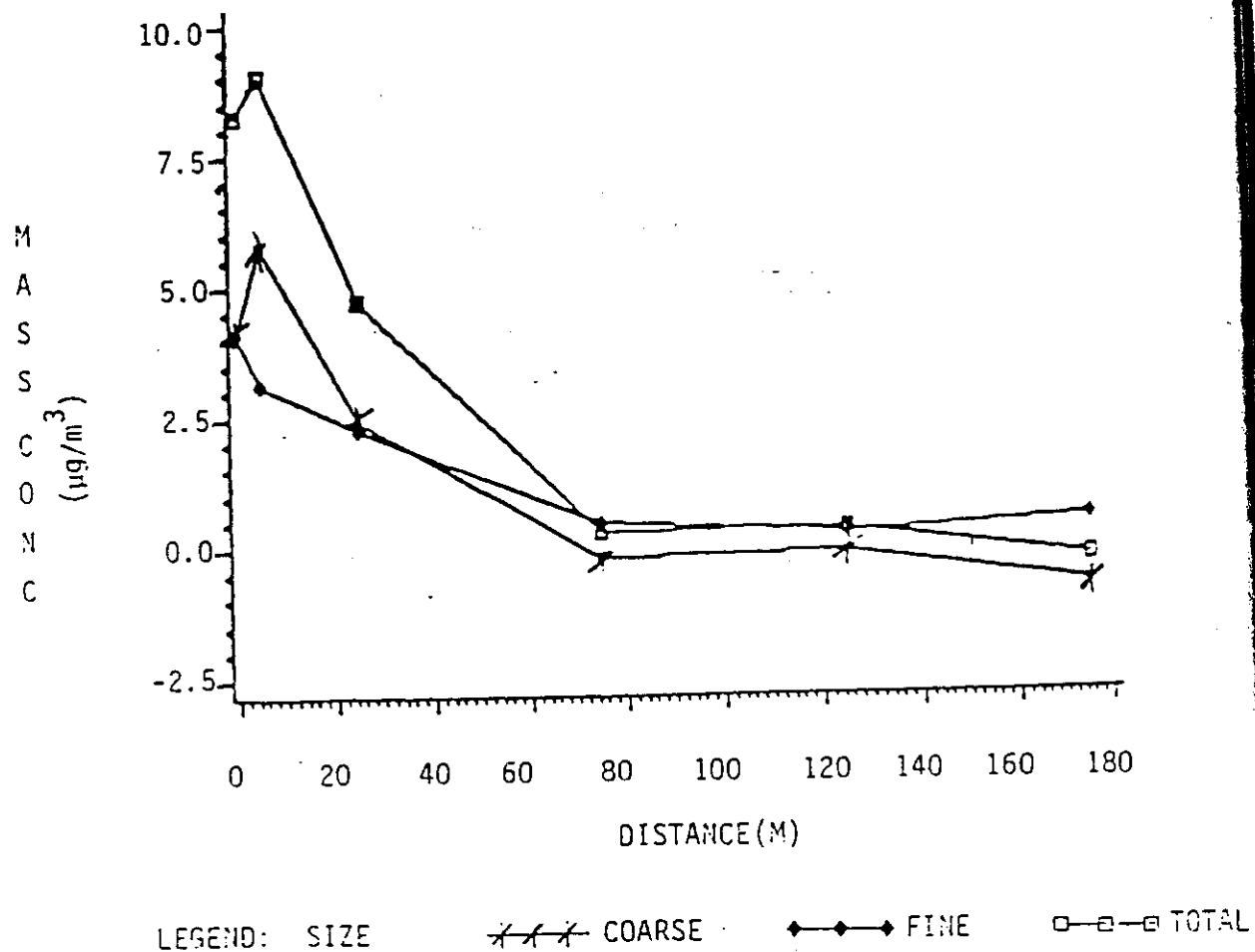


Figure 22. Average measured PM concentrations (downwind less upwind) from a major Philadelphia highway (Burton and Suggs 1982).

When two sites are needed to monitor background concentrations, one station should be selected that is upwind of the area of concern most frequently or downwind least frequently. If this site cannot be clear of contributions from nearby sources for all wind directions, a second site is required. This site should be selected to supplement information obtained from the first site to the maximum extent possible, so that one site or the other is measuring the background level at all times. One strategy is to place the second site in the direction that is upwind of the area of concern second most frequently. If the first and second most frequent wind directions are more than  $120^\circ$  apart, this may be a good plan. If they are less than  $90^\circ$  apart, both sites may be downwind of the primary area of concern or of the same large source on the same day. This risk can be minimized by selecting a second site that has bearing from the primary area of concern that is  $180^\circ$  from the bearing to the first site. A climatological wind rose showing the frequency with which the wind blows in each direction is useful for selecting sites. The map of circled major sources may be used to show areas that are not affected by major sources for specific wind directions. Figure 23 shows an example. In this case the monitoring agency must select a site within 24 km (15 miles) of its offices. However, the impact zone of the city (City A) extends out 90 km, so the agency must monitor on both sides of the city. The most frequent and second most frequent wind directions, shown in the lower right-hand corner of the figure, are about  $120^\circ$  apart. However, a site directly south of the city is not desirable because of interference from City D. An alternative site slightly to the east of south would still be representative for south winds and less affected by City D. Another alternative site is  $180^\circ$  from the direction for which the first site was selected. Selected regional scale monitoring sites should not be influenced by topographical features. Sites along shorelines, in or at the base of pronounced valleys, near sharp bluffs, or in low-lying areas should be avoided. The topography around the most suitable sites is uniform.

#### Urban Areas with No Major Point Sources

Some urban areas will have no major sources of  $PM_{10}$  emissions. Because most of the measured IP concentrations come from geological materials, from motor vehicle traffic, or from secondary aerosols formed in the atmosphere (EPA 1981; Watson, Chow, and Shah 1981), this may be the situation in a number of areas for which monitoring is planned. Figures 19 and 20 describe steps that may be used to select monitoring sites in such situations.

The first step is to obtain and analyze traffic and urban development data that can be used to identify potential variations in otherwise homogeneous neighborhood scale patterns of  $PM_{10}$  concentrations. Areas of high traffic density, such as major highways, shopping centers, sports areas, amusement parks, airports, and parking facilities, need to be identified and analyzed. Also, areas that are concentrated sources of particulate matter emissions, such as solid waste handling facilities, unpaved roadways, central business districts, and construction operations, need to be analyzed.



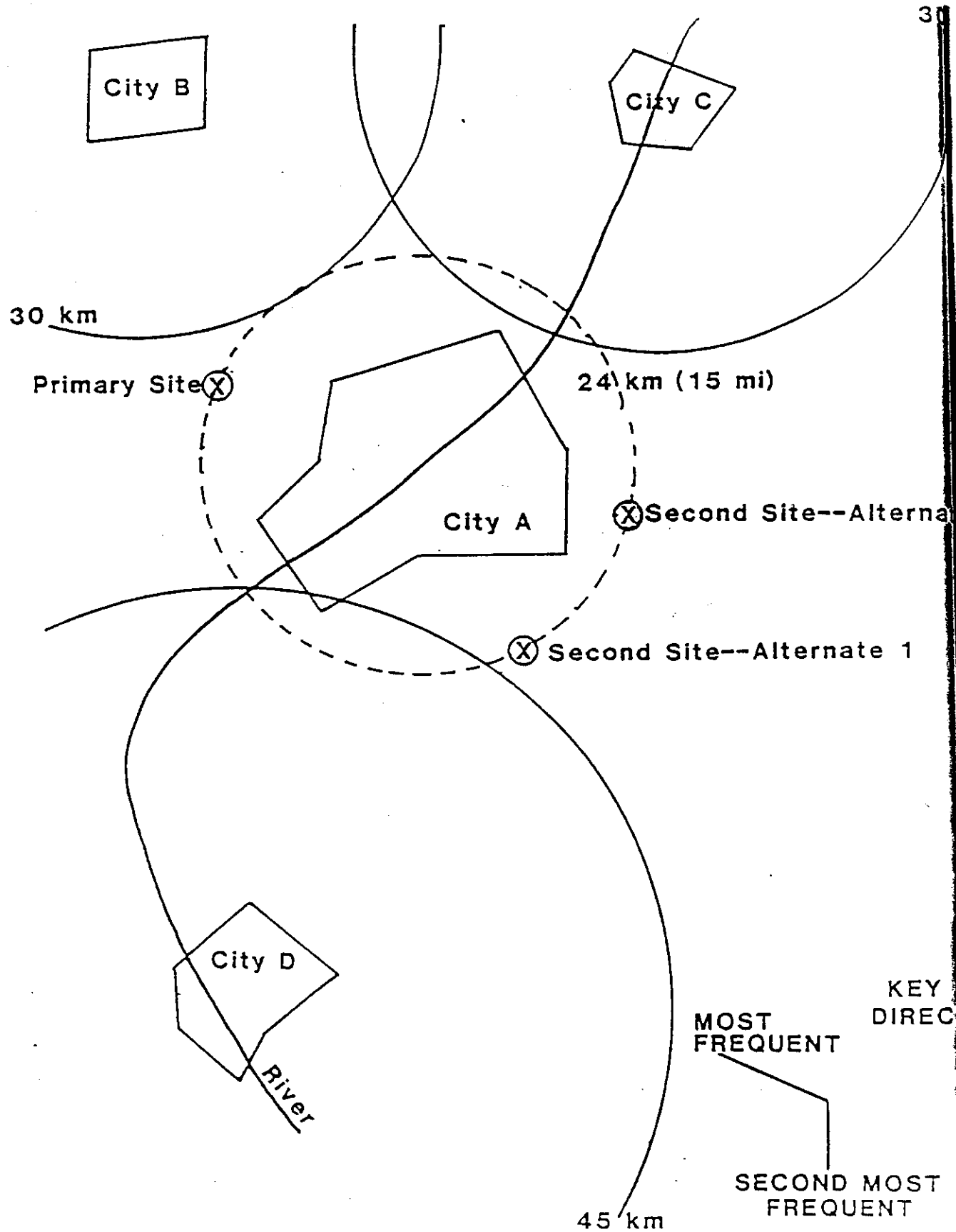


Figure 23. Example of background site selection within 24 km (15 mi) of City A.

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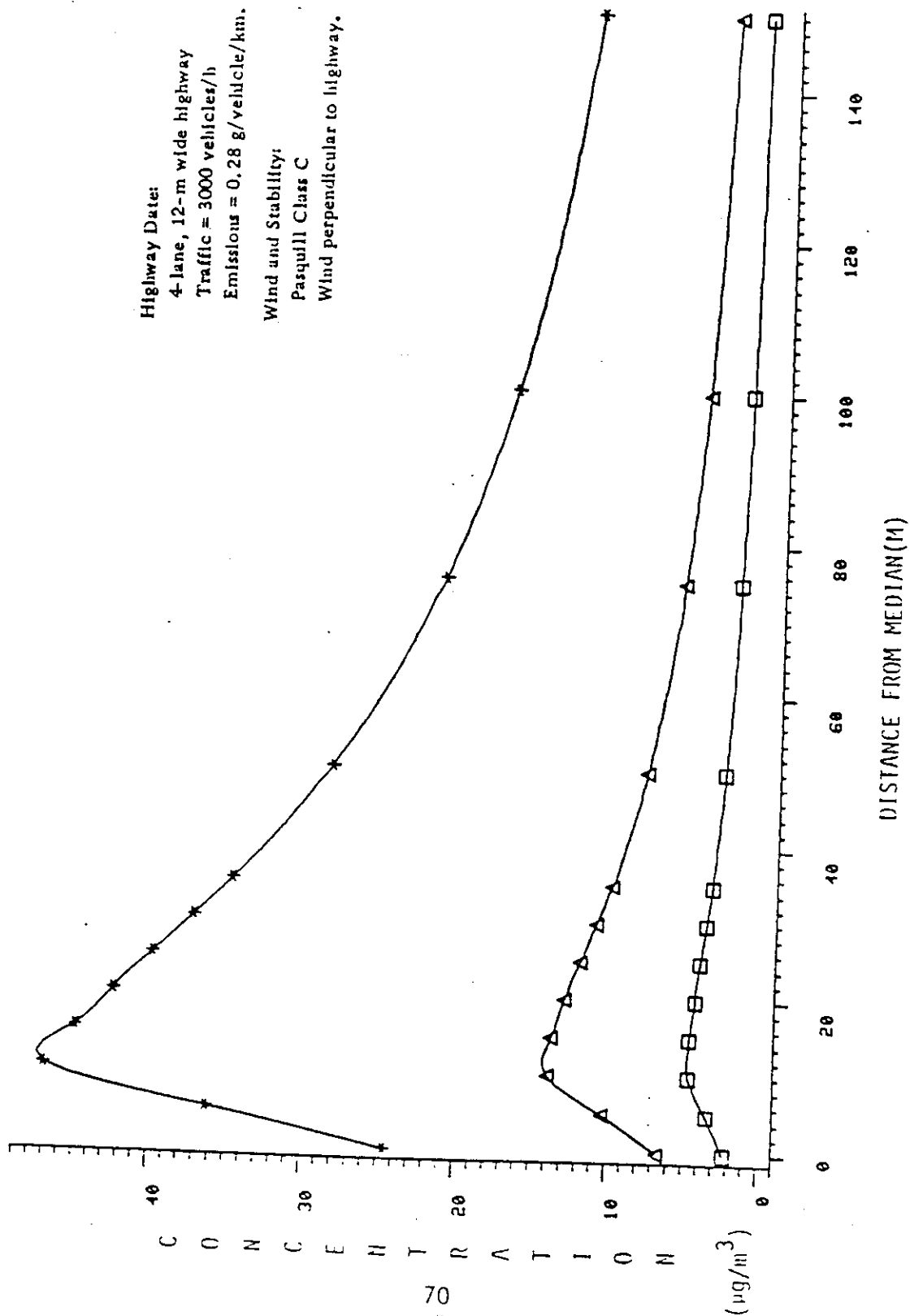
Figures 24 through 26 show the model peak concentrations downwind of highways that occur within 15 m of the roadway. Data in Table 12 show the peak concentrations expected downwind of other sources that are centers of intensive traffic-generated emissions. These guides can be used to estimate where the pollution increases above general neighborhood levels will occur, which can be expected in the vicinity of these sources.

On the basis of the magnitudes of the  $PM_{10}$  enhancement predicted for all the traffic-concentrated areas and the locations of the source areas relative to the downwind edge of the city for the most prevalent wind direction, a decision must be made on how many monitors will be used to measure the maximum  $PM_{10}$  concentration. Unless a single source or source area is clearly more significant than any other, a number of sites should be selected as potential peak concentration monitoring sites. These sites will be representative of micro- or possibly middle scale areas. The monitoring site should be located as close to the source as possible without infringement or interference from the source. The most suitable sites are within 5 to 15 m of the sources on the downwind side of the prevailing wind direction. It is usually not practical to locate a site less than 5 m from a source. Generally, one site is sufficient for each source area.

Neighborhood sites are needed to represent the areas that encompass or surround the peak concentration sites. Due to variations in the type and intensity of land uses throughout an urban area, a large metropolitan area may be characterized by well over 1000 different neighborhoods. The process of identifying and classifying all neighborhoods in a metropolitan area in terms of their potential  $PM_{10}$  air quality levels is a worthwhile effort for air pollution control planning purposes. The use of monitoring or modeling data is the most satisfactory way to making such classifications. However, it is also possible to characterize neighborhoods in a qualitative fashion by preparing a detailed emission inventory that identifies the spatial distribution of emissions from the many indirect and fugitive sources of  $PM_{10}$ .

By examining the locations and magnitudes of these sources in relation to the climatology of wind direction frequencies, one can rank neighborhoods in terms of their expected levels of high  $PM_{10}$  concentrations. Neighborhoods that encompass the middle or microscale areas that are expected to contain high concentrations are clearly high priority neighborhoods for monitoring sites. One or two neighborhoods adjacent to the maximum concentration neighborhoods are desirable secondary sites. A third category of monitoring sites includes neighborhoods that are of special interest because of large population density; because of rapid growth expectations; or because of a highly sensitive population such as elderly (e.g., nursing home), ill (e.g., hospital), or young (e.g., day care center).

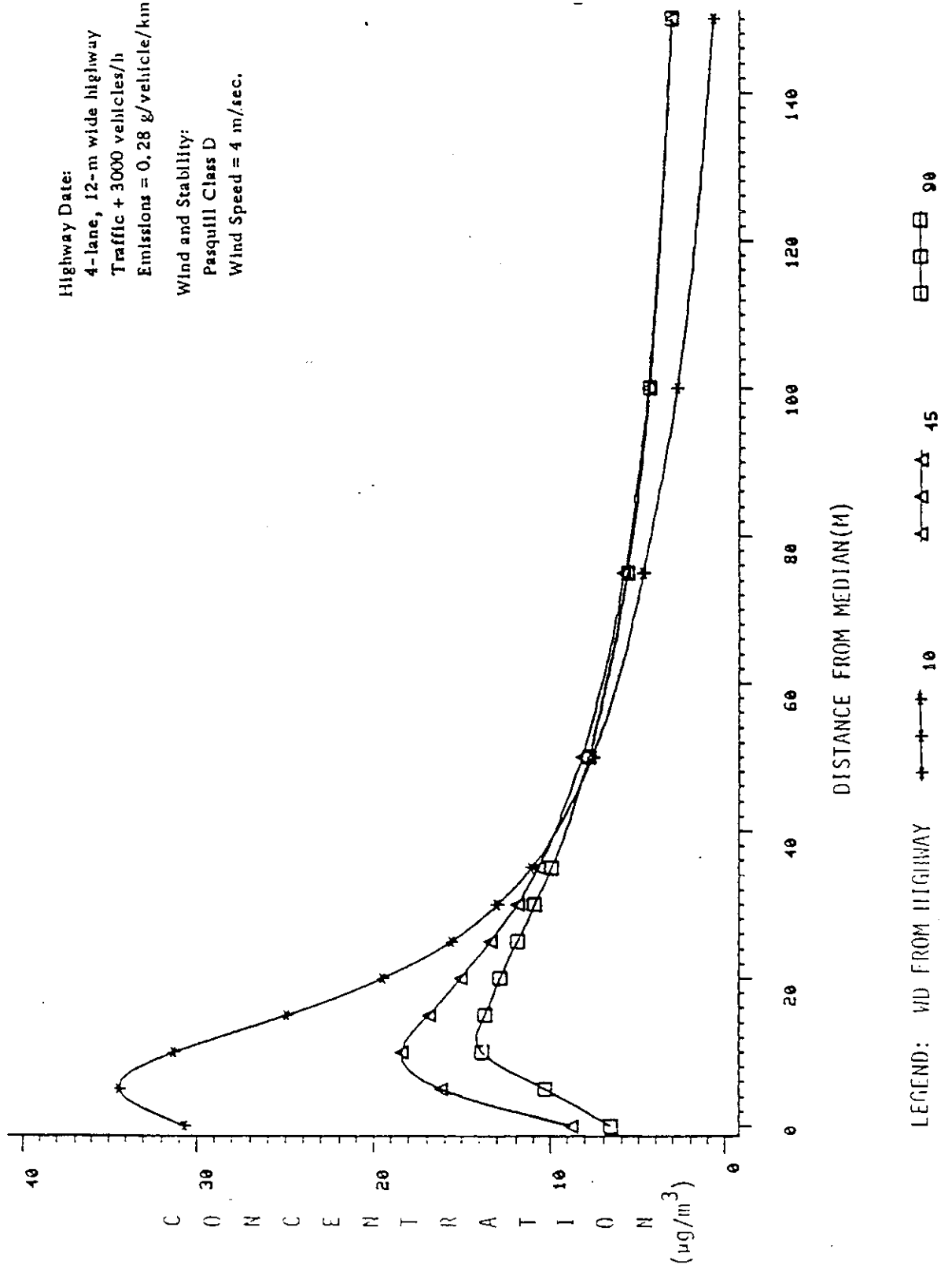
Sites in the third category of interest may also meet the second category of interest. There are no firm rules to determine how many sites to monitor. Each monitoring jurisdiction must determine what its priorities are and how far down the priority list of potential sites it is able and willing to go.



Highway Data:  
 4-lane, 12-m wide highway  
 Traffic = 3000 vehicles/h  
 Emissions = 0.28 g/vehicle/km.

Wind and Stability:  
 Pasquill Class C  
 Wind perpendicular to highway.

LEGEND: WIND SPEED (m/sec)    +    Δ    □    4    12



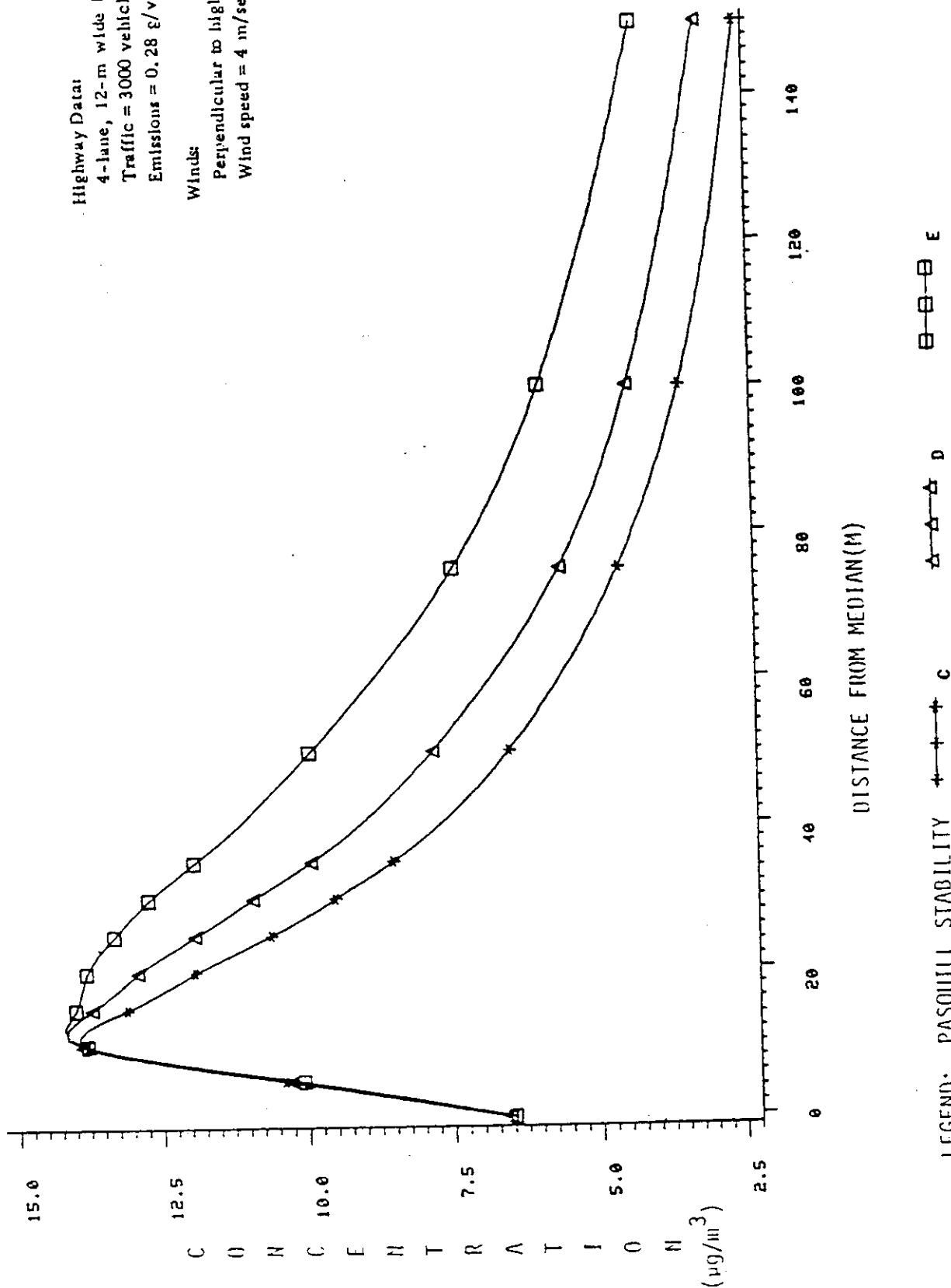


Figure 26. Concentration as a function of stability class, computed using HIRSH model.

TABLE 12. MAXIMUM CONCENTRATIONS NEAR DOWNWIND  
EDGE OF TYPICAL URBAN AREA SOURCES

| Type Source          | Typical Maximum 24-hour<br>Concentration ( $\mu\text{g}/\text{m}^3$ ) | References            |
|----------------------|---|-----------------------|
| Urban Expressway (1) | 85  | Burton and Suggs 1982 |
| Street Canyon (2)    | 45  | Ingalls 1981          |
| Parking Garage* (3)  | 45  | Ingalls 1981          |
| Roadway Tunnel (2)   | 650   | Ingalls 1981          |
| Shopping Mall (4)    | 80  | Ingalls 1981          |
| Sports Stadium* (4)  | 10  | Ingalls 1981          |

\* Very high short term concentrations may occur near this source.

- (1) Based on observed upwind-downwind differences in IP over 14 hours, corrected to 24 hours and  $\text{PM}_{10}$ .
- (2) Based on a 24-hour average to peak ratio of 0.5, a vehicle emission rate of 0.28 g/km, and a peak traffic flow of 3000 vehicles/hour.
- (3) Based on model estimates and an emission rate of 0.085 g/min.
- (4) Based on CO observations of 2.5 ppm (24 h) for shopping centers, and 22 ppm (15 min) for sports stadiums, and ratio of  $\text{PM}_{10}$  to CO emissions of 0.0286.

Table 13 illustrates a rationale for selecting 15 sites. In this example, four neighborhoods are identified that potentially have high micro- and middle scale PM<sub>10</sub> levels. The neighborhoods that border on a neighborhood containing high concentrations are also expected to have a chance of exceeding the NAAQS for PM<sub>10</sub>. As a result, two sites in adjacent neighborhoods will be selected. There are also three neighborhoods that contain health care treatment facilities with persons who are highly sensitive to air quality. After discussions with various officials responsible for providing funds for air monitoring operations, a decision is made to put monitors at 15 sites.

TABLE 13. EXAMPLE DETERMINATION OF THE NUMBER OF MONITORING SITES IN A METROPOLITAN AREA\*

| Priority | Type of scale for PM <sub>10</sub>            | Recommended number of sites | (X) Number of areas | (=) Number of sites |
|----------|---|-----------------------------|---------------------|---------------------|
| 1        | Includes selected micro- or middle scale site | 1                           | 4                   | 4                   |
| 2        | Adjacent to major source area                 | 2                           |                     | 8                   |
| 3        | Special interest                              | 1                           | 3                   | <u>3</u>            |
| Total    |   |                             |                     | 15                  |

\* This case was selected to be representative of a city with a population of 500,000 and four major source areas. Smaller cities and cities with fewer source areas may require fewer monitoring sites.

Each neighborhood selected for monitoring must be reviewed carefully to identify areas containing micro- or middle scale PM<sub>10</sub> effects. Neighborhood scale sites must be selected to avoid these areas. The data presented in Tables 14 through 16 identify the distances to which middle scale effects extend from the types of sources associated with PM emissions. These distances should be shown as circles around sources in neighborhoods selected for monitoring.

TABLE 14. SIGNIFICANT IMPACT DISTANCES OF  
SMALL GROUND-LEVEL AREA SOURCES

| Area (m x m)                      | Emission<br>rate (kg/km <sup>2</sup> /day) | Maximum downwind distance (km)<br>with significant impact* |
|-----------------------------------|--|--|
| 250 x 250                         | 10   | 0.25   |
|                                   | 10 <sup>2</sup>                            | 1.0  |
|                                   | 10 <sup>3</sup>                            | 5  |
| 500 x 500                         | 10   | 0.6  |
|                                   | 10 <sup>2</sup>                            | 2.5  |
|                                   | 10 <sup>3</sup>                            | 14   |
| 10 <sup>3</sup> x 10 <sup>3</sup> | 10   | 1.4  |
|                                   | 10 <sup>2</sup>                            | 7  |
|                                   | 10 <sup>3</sup>                            | 45   |

\* Based on 24  $\mu\text{g}/\text{m}^3$ , F stability class and 2 m/sec wind speed. Estimated using Workbook of Atmospheric Dispersion Estimates (Turner 1970) by treating source as a point. This worst case situation is expected to produce a 24-hour concentration of 6  $\mu\text{g}/\text{m}^3$ .

TABLE 15. SIGNIFICANT IMPACT DISTANCES OF HIGHWAYS

| Average<br>daily traffic (veh/day) | Maximum downwind distance (km)<br>with significant impact* |
|------------------------------------|--|
| 100,000                            | 0.22   |
| 50,000                             | 0.11   |
| 25,000                             | 0.05   |
| 15,000                             | 0.02   |
| 12,000                             | 0  |

\* Based on 6  $\mu\text{g}/\text{m}^3$ , Pasquill stability class D, and wind speed of 2 m/sec at 45 degree angle with highway. Estimated using EPA HIWAY2 model and vehicle emission rate of 0.28 g/km. Because concentrations downwind of highways are not sensitive to variations in wind direction, the worst case 24-hour concentration is based on a persistent worst case 1-hour concentration. This allows the effect to be comparable with worst case effects from elevated points (Table 16) and small areas (Table 14).



TABLE 16. SIGNIFICANT IMPACT DISTANCES OF ELEVATED SOURCES

| Effective plume height (m) | Emission rate (kg/hr) | Critical Pasquill stability class | Maximum downwind distance (km) with significant impact* |
|----------------------------|-----------------------|-----------------------------------|---|
| 30                         | 30                    | C                                 | 3.3   |
|                            | 10                    |                                   | 1.7   |
|                            | 3                     |                                   | 0.9   |
| 100                        | 100                   | A                                 | 1.2   |
|                            | 30                    |                                   | 0.8   |
|                            | 10                    |                                   | 0.5   |
| 300                        | 100                   | A                                 | 1.2   |

\* Based on  $24 \mu\text{g}/\text{m}^3$  and 2 m/sec wind speed. Estimated using Workbook of Atmospheric Dispersion Estimates (Turner 1970). This worst case situation is expected to produce a 24-hour concentration of  $6 \mu\text{g}/\text{m}^3$ .

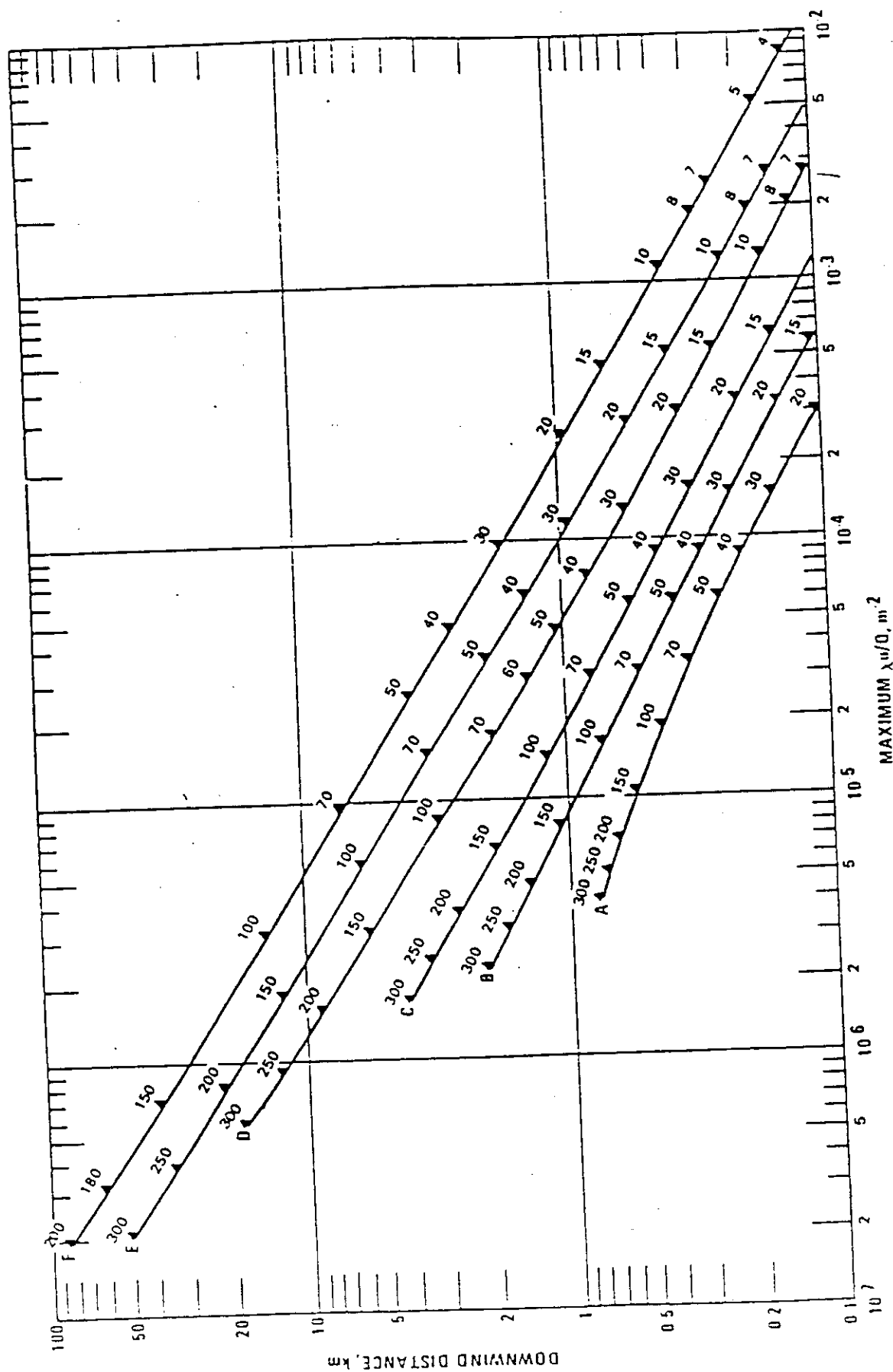
#### Monitoring Isolated Major Sources in Flat Terrain

Figure 20 suggested steps to be followed in selecting monitoring sites near an isolated major source. A distinction must be made between sources with the principal emissions from a tall stack and sources with the principal emissions from ground level. For ground-level sources, the maximum concentrations will occur immediately adjacent to the source in the most prevalent downwind directions from the source. Wind observations will easily identify the most suitable siting areas. Additional monitors may be used to help define the extent of the area near the source that has high concentrations and the neighborhood scale level of  $\text{PM}_{10}$  in the vicinity of the source. Two types of information can be helpful in determining the extent of the high impact area: (1) the relative concentration isopleths from the EPA (1970) Workbook of Atmospheric Dispersion Estimates and (2) annual wind direction frequency statistics published by the National Climatic Center (see Appendix A).

It is easily seen from the Workbook data that the peak concentration falls off rapidly with distance for ground-level sources. The peak concentration 100 m from the source drops by a factor of 10 at a distance of 40 km from the source for all stability conditions. The more stable the atmosphere, the more slowly the peak concentration drops with increasing distance from the source. The Workbook curves show that even for very stable conditions (Pasquill Class F), the peak concentration drops by a second factor of 10 within 1600 m from the source. These data show the microscale influences within 100 m of the source are at least 10 times greater than the middle scale influences from 100 to 500 m from the source. If there is public exposure within 100 m, it is important to locate a monitor there. Middle scale monitoring sites within 500 m of the source are desirable in each prevailing wind direction. One of the middle scale sites should be downwind for the wind direction that occurs most frequently with stable conditions and low wind speeds. A Star climatology analysis for the closest weather observing station maybe used to determine this direction (see Appendix A).

If the primary emissions are from a tall stack, the highest ground-level concentrations will be away from the source. Detailed manual computational procedures for estimating the magnitude and location of the maximum impact of tall stack emissions are given in Volume 10 of the EPA Guidelines for Air Quality Maintenance Planning and Analysis (Budney 1977). Figures 27 and 28 (taken from Budney 1977) show how the distance to the maximum short-term concentration varies with the effective height of the exhaust gas plume and atmospheric stability. Figure 27 treats sources in rural terrain, and Figure 28 treats sources in urban terrain. Budney's Guideline describes a method of estimating the effective height of the source. Because the PM<sub>10</sub> monitors will observe 24-hour and annual mean concentrations, the large variation in distance to the maximum concentration with variations in atmospheric stability class must be taken into account in selecting a site. It may be noted in Figure 27 that the maximum concentrations occur with the greatest instability (i.e., Class A). Therefore, it is important to site a monitor close to the source where the maximum contributions will occur under unstable conditions. As shown by Figure 27, this will be as close as 100 m to a source with a 20 m effective height and as far as 800 m downwind of a source with a 300 m effective height.

Another important factor in selecting a site is the persistence of the wind direction over the observation period. Because the wind direction is highly variable under unstable conditions and because persistent wind directions are generally associated with neutral (Class D) stability conditions, a good strategy is to select a second monitoring site at a distance associated with the peak for neutral stability. The distance downwind to the peak concentration will vary from about 350 m for an effective height of 20 m to between 15 and 20 km for an effective height of 300 m.



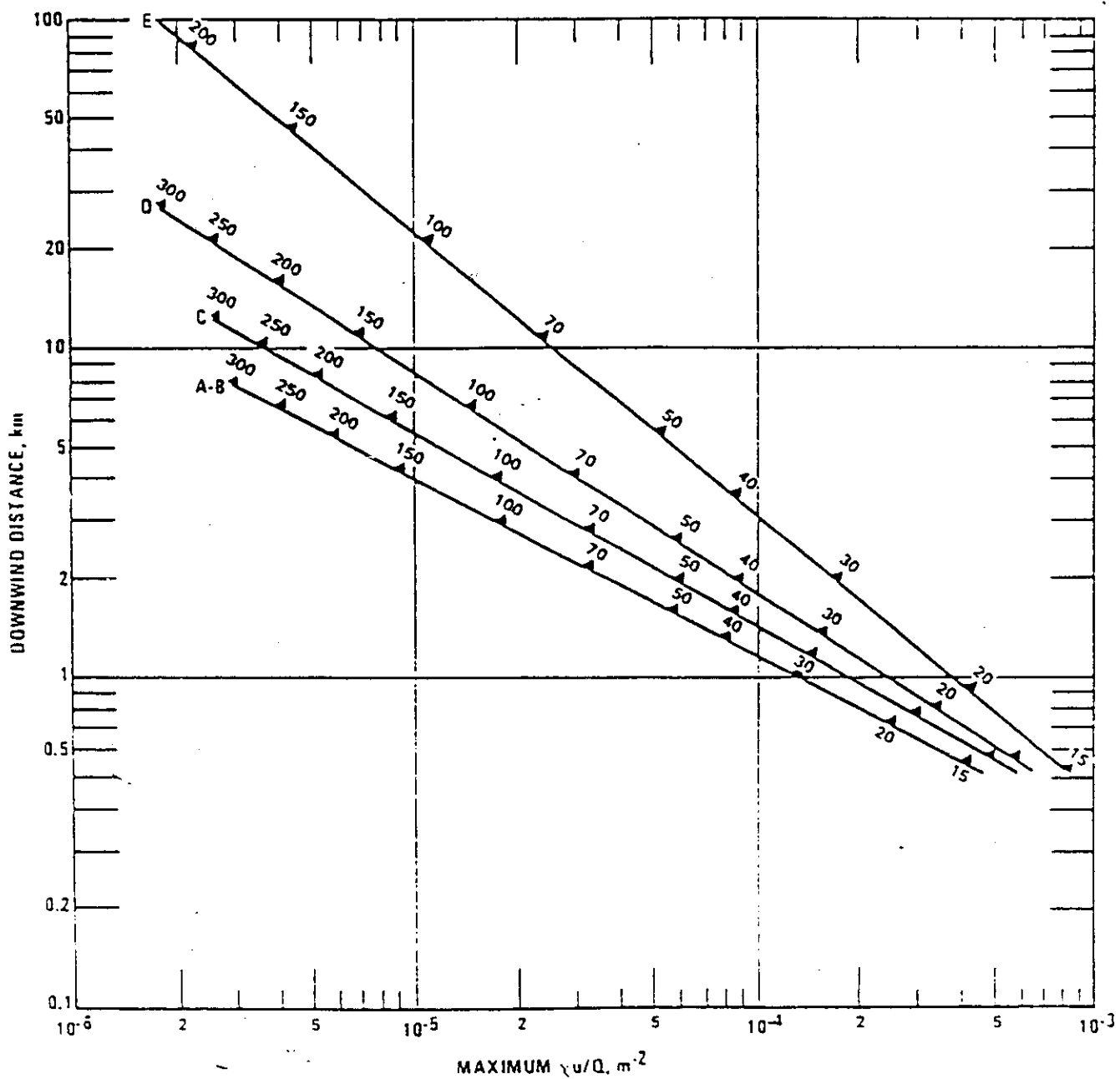


Figure 28. Downwind distance to maximum concentration and maximum  $\chi u/Q$  as a function of stability class and effective plume height in urban terrain (Budney 1977).

The peak concentration will be sharp, with high concentrations falling off rapidly with distance from the peak, when the peak is close to the source. This is a middle-scale effect, and the maximum impacts will be observed over an area within 200 to 300 m of the peak. The frequency of wind directions associated with only unstable conditions should be taken into account in selecting sites for observing the middle-scale peak.

When selecting a site to observe concentrations from a tall stack (effective height of 100 m or more) during persistent wind conditions (and neutral stability), the concentrations will fall off gradually with distance from the peak. The impacted area will be on a neighborhood scale, with high concentrations (within 25 percent of the peak) occurring at distances of 2 km from the peak when the effective height is 100 m and to distances of 10 km when the effective height is 300 m. Wind direction frequencies associated with neutral conditions should be used to site monitors. It may be noted that there is a large area within which to select a site.

Wind observations from remote sites (e.g., a regional airport) are very useful for selecting neighborhood-scale sites. When selecting a middle-scale site, it is necessary that the wind observations be representative of the very small scale area in the vicinity of the site. In the next section, topographical influences are discussed that may make wind observations unrepresentative. Suggestions are made for taking the local influences into account in selecting monitoring sites.

#### Monitoring Isolated Major Sources in Complex Terrain

There are a number of situations in which the complexity of the terrain in the vicinity of a major source will influence how pollutants are distributed in the nearby vicinity. These influences must be taken into account in siting monitors if the observations are going to achieve their objectives. Available meteorological observations may not be adequate to describe the effects, especially if they are taken from a single site. In particular, the effects of elevated terrain, coast lines, and urban structures need to be taken into account. The air flow characteristics in the vicinity of these types of terrain were discussed in Section 4. Suggestions are given here for using the topographical characteristics of an area to select monitoring sites and to modify the site selection guidelines for flat terrain.

Typical influences due to elevated terrain include two-sided boundaries such as a valley and one-sided boundaries such as a mountain range or a pronounced bluff. Air flow in a valley is subject to nighttime drainage down the slopes and along the valley floor, to upslope convection and fumigation during the day, and to channeled flow when strong winds blow diagonally across the valley. Near one-sided boundaries, emissions on the downwind side of a ridge or hill may become entrapped in the turbulent wake flow downwind of the ridge, or separated from ground-level when overshoot separation flow occurs over the ridge. Emissions near either one-sided or two-sided terrain boundaries may impact the terrain under very stable conditions with the flow

directed towards the elevated terrain. Each of these effects produces a pollution impact zone, which is associated with the terrain configuration. Monitoring sites are needed that measure the results of these effects. The following terrain-oriented sites are needed to supplement or replace sites that conform to flat terrain siting selections:

- Down- and up-valley in place of or in addition to downwind of the most prevalent wind directions
- Terrain elevation at the effective height of the source plume or at maximum elevation (if less than effective height) in prevailing downwind directions
- Nearest terrain elevation at effective height of source plume.

Near a lake or ocean coast, there will be an invisible boundary between the air influenced by the temperature of the underlying water surface and the air influenced by the temperature of the underlying land surface. A great difference in the two surface temperatures can significantly alter air flow in the vicinity of the coast line. The two effects that are of interest in selecting sites for monitors are (1) the tendency for the air flow to be perpendicular to the coast and (2) the formation of a vertical circulation with its axis centered on the coast line. The first effect indicates the need for a monitoring site directly inland from a source near the coast. The second effect indicates the need to have sites along the coast on both sides of the source. These sites are to catch the impact of air that initially moves inland, but that subsequently rises, moves back over the water, sinks, and blows back inland at low levels. Under these conditions, pollution moves perpendicular to the apparent ground-level wind observations. The magnitude of the air pollution effect from this recirculation of air over the coast line is difficult to anticipate. It could be an important, controversial contribution to establish. These siting considerations should be taken as supplements to the guidelines given for more uniform terrain situations.

#### Urban Areas with Major Point Sources

When major point sources of PM emissions are present in an urban area, there is a need to consider the impacts of the point and the urban area sources individually and of their joint overlapped effects. Siting considerations relating to both urban areas and points as individual sources were previously discussed. The overlapped effects can be best identified by considering lines connecting pairs of nearly individual sources. When the connecting lines parallel one of the prevailing wind directions, locations that are downwind of both sources and near the maximum of the second downwind source are likely locations of maximum 24-hour PM<sub>10</sub> concentrations. However, the maximum annual mean concentration is likely to be in a location that is central to the individual sources. Such a location will be affected

by different sources at different times, rather than by the simultaneous overlapping of the effects of two or more sources. These two qualitative criteria regarding the impact of overlapping effects can be used to help identify locations that are probably sites of maximum concentrations. These criteria are helpful when a modeling analysis is not available to evaluate the joint effects of multiple sources.

Simple calculations and graphical analysis may be used to apply the above siting criteria for multiple sources. For instance, in deciding which pairs of overlapped source contributions are most significant, the relative emission sites and distances between sources should be taken into account. The contribution of a source to the PM<sub>10</sub> concentration at any location is directly proportional to the emission rate and inversely proportional to the distance from the source. Although the distance relationship is a complex function of atmospheric stability conditions and the effective height of the emissions, the distance effect is most frequently very nearly proportional to the inverse square of the distance. For the purpose of evaluating the importance of overlaps from the sources, the following relationship can be used:

$$A = \frac{E}{D^2}$$

where A = Relative contribution from second source  
E = Emission rate (second source)  
D = Distance to second source.

To illustrate the use of this relationship, consider a major urban freeway with a nearby source only 0.5 km away that emits 10 lb/hr. The overlap contribution from the source will be more important than any other source emitting 100 lb/hr or less at a distance of 1.6 km or more away, since

$$A_1 = \frac{10}{(0.5)^2} = 40$$

$$A_2 = \frac{100}{(1.6)^2} = 39$$

A good way to define the scale and locations of the effect of overlapped sources is to construct a representative graph of peak concentrations versus distance downwind of the second source. This can be done quite easily by the use of the EPA Workbook of Atmospheric Dispersion Estimates (Turner 1970) or

Volume 10 of the EPA Guidelines for Air Quality Maintenance Planning and Analysis (Budney 1977). The following steps may be used:

1. Pick a representative stability condition (e.g., C stability) and find the appropriate  $xu/Q$  versus distance graph.
2. For the larger of two overlapping sources, use the selected graph to find a dozen pairs of  $xu/Q$  and distance values that straddle the peak  $xu/Q$  value, and multiply the  $xu/Q$  values by the emission rate to get  $(xu)_1$  values.
3. Add the distance (D) between the two sources to the distances read in step 2 and read a new  $x/Q$  value from the graph for each new distance.
4. Multiply the second set of  $xu/Q$  values by the second source emission rate to get  $(xu)_2$  values.
5. Add the two sets of  $xu$  values together and plot the sum as a function of the initial distance (without D added).
6. Repeat steps 2 through 5 for additional distances to make the curve complete.

Table 17 shows a sample work table for use with the above steps. The procedure may be repeated for more than one stability class to help identify a range of distances from the source within which the maximum concentrations will occur. The buildup and fall off of concentration with distance will help identify the distance scale that the combined concentrations will affect.

TABLE 17. SAMPLE WORK TABLE FOR OVERLAP EFFORTS

| Distance<br>from larger<br>source (x) | $(xu/Q)_1$ | $(xu)_1$ | Distance<br>from smaller<br>source (x+D) | $(xu/Q)_2$ | $(xu)_2$ | $(xu)_1$<br>+<br>$(xu)_2$ |
|---------------------------------------|------------|----------|--|------------|----------|---------------------------|
|---------------------------------------|------------|----------|--|------------|----------|---------------------------|



This procedure is expected to be adequate for most monitor siting purposes. However, the graphs referenced above do not include any effects of particle removal due to fallout or other atmospheric processes. Actual concentrations may decrease more rapidly with downwind distance than is represented by these curves. More accurate graphical representations of the relationship may become available in the future and should be used when appropriate.

When considering sites to measure long-term concentrations that include contributions from many sources, a simple numerical evaluation procedure may be used to help select the best sites. Over a long-term period, both the distance from the source and the frequency with which the wind blows from each source to the potential monitoring site must be taken into account. The following simple source weighting function takes these two effects into account:

$$B = \sum_{i=1}^N \frac{E_i f_i}{(D_i)^2}$$

where B = Monitoring site pollution index

$E_i$  = Source i emission rate

$f_i$  = Relative frequency with which wind blows from source i to the monitoring site

$D_i$  = Distance from source i to monitoring site

N = Number of urban area and major point sources.

This site evaluation equation may be used to rank alternative monitoring sites. The best way to perform the site evaluation process is to plot the major urban area and major point sources on a map. A number of locations in the middle of the sources and close to or downwind of the larger sources may be selected as potential monitoring sites. The evaluation equation may then be used to score the relative pollution levels expected at each potential site. The highest score would indicate the site most likely to measure the highest PM<sub>10</sub> concentration.

## SELECTION OF MONITORING SITES

### Number and Locations of Monitors

The preceding steps have been concerned with developing a pattern of PM<sub>10</sub> air quality that occurs in an area of concern for which monitoring is planned. This may be an area administered by an air pollution control agency or an area impacted by a particular source. In either case, there are

three types of information regarding the patterns which are of interest, including:

- Maximum PM<sub>10</sub> concentration
- Background PM<sub>10</sub> concentration
- Area impacted by significant PM<sub>10</sub> concentrations.

Significant PM<sub>10</sub> concentrations may be levels associated with air quality standards, PSD increments, specific increments above background levels, or other criteria of interest. There is another type of site that does not involve a selection process (i.e., sensitive sites of special interest). In a simple pattern, there will be one maximum and a single regularly shaped contour that defines the area impacted by significant concentrations. Complex patterns have two or more peaks that may or may not lie within a single closed contour of impacted areas of interest. Unless one peak is much higher than the others, two or more peak areas will need to be monitored.

The number of monitors needed to define impacted areas will include a minimum of two and may include six or more depending on how large, how complex and how definitive the impacted area is. A single, well-sited monitor, located well away from any nearby sources or source areas, may be adequate for determining background concentrations. If it is impractical to locate a monitor far away from nearby sources, it may be desirable to select two nearby monitors, one or more of which is measuring background concentrations on any given day, depending on wind direction. Because PM<sub>10</sub> concentrations are measured over 24-hour periods and because the wind direction is frequently variable over a 24-hour period, this is a less desirable option than a single, well-sited monitor.

In planning and revising air monitoring plans, it is important to bear in mind that the need for monitoring data is dynamic and will change from year to year. Once the nature of the air quality pattern for PM<sub>10</sub> concentrations has been established or verified, fewer stations are needed to evaluate general ambient conditions and trends. This is especially true for areas where the ambient levels are well within acceptable limits and there is no significant impact area. Reducing the amount of resources allocated to fixed monitoring stations will allow resources to be reallocated to meet other special purpose monitoring needs.

Previous monitoring and modeling provide a first estimate of the PM<sub>10</sub> air quality patterns, but a large amount of uncertainty may still exist regarding both the shape and the magnitude of the pattern. Therefore, some monitoring resources should be allocated to verifying the assumptions made regarding the pattern. Two forms of monitoring are recommended for this purpose, including temporary sites and mobile monitoring. This type of monitoring is most effective when it is used in conjunction with modeling results to confirm or deny the influence of specific sources on air quality levels. An example of appropriate use of this type of monitoring is to

establish the validity of a kink or a bulge in the air quality pattern due to the influence of a specific nearby source or source area. Modeling results could be obtained to show the expected contribution of specific sources to the bulge. Air monitoring results along with appropriate meteorological data could be used to establish the validity of the influence. A temporary monitor could be moved from one location to another to investigate the validity of a number of these influences. The monitoring results would increase confidence in the modeling results or provide the basis for either model improvements or selection of a more accurate model.

Mobile monitoring can also be used to help establish the influence of specific sources. Mobile monitoring is effective when it is used to identify peaks in concentrations during crosswind sampling traverses downwind of large elevated point sources. Another effective use of mobile monitoring is to encircle area sources in order to establish concentrations upwind and downwind of suspected significant sources of ground-level fugitive emissions. A limitation in mobile monitoring is the need to use a continuous type of analyzer. Continuous measurements of PM will necessarily be based on physical measurement other than the weight of size-selected particulate matter collected on a filter. As a result, it will be necessary to correlate the mobile measurements with fixed station measurements before interpreting the mobile measurement data. Some guidelines on ways of making these correlations are provided in the Guidelines for PM-10 Episode Monitoring Methods (Pelton 1982).

#### Specific Site Selection

Once a general area for a monitoring site has been selected, it is necessary to select a specific location for the sampling operation. The intake for the monitor must be representative of the siting area, as close to the breathing zone as possible, and not biased abnormally high or low by influences which are only representative of the probe intake. The nature of biasing influences is documented in CFR 40 Part 58 and includes the following:

- Chemical reactions due to the air stream passing near reacting surfaces
- Unusual micrometeorological conditions
- Vegetation that serves as a pollutant sink
- Undue influence from nearby small sources (e.g., incinerator or furnace flue)
- Shielding influences from nearby obstructions.

Based on the consideration of these factors, the following guidelines for siting problems were promulgated in CFR 40, Part 58:

- 2-15 m above ground, as near to breathing height as possible, but high enough not to be an obstruction and to avoid vandalism
- At least 2 m away horizontally from supporting structures or walls
- Should be 20 m from dripline of trees
- Should not be near furnace or incinerator flues
- No nearby obstructions to air flow due to buildings, structures or terrain, at least in directions of frequent wind.

These guidelines were provided for TSP but are equally applicable to PM<sub>10</sub>.

#### INSTALLATION AND FOLLOWUP

Each time a monitoring site is established, a documented description of the site is established. This record will help in the interpretation of results obtained from the site and in the evaluation of the need for changes. The following information is useful in documenting a site with regard to effects on measured PM<sub>10</sub> concentrations:

- Exposure diagram
  - Horizontal depiction showing location relative to nearby streets, buildings, and other significant structures, terrain features, or vegetation
  - Vertical depiction showing location relative to supporting structures, including buildings, walls, etc.
- Height of sampling intake above ground level
- Microinventory map showing locations of roads (with traffic counts), open fields, storage piles, and any visible emissions within 500 m of sampler
- List of all inventoried point and area sources within 1.5 km of sampler and all major point sources within 8 km of sampler

- Make and model of PM<sub>10</sub> monitor
- Types of meteorological and other air monitoring equipment operated at the site.

Once a monitoring site is selected and approved, the above site information should be compiled. As soon as it is practical, data collected from the site should be reviewed and scrutinized to determine that they do not contain undue influences from nearby sources. The suggestions for analyzing single-station air quality records, presented earlier in this report, should be used to evaluate the observations.

## SECTION 6

### EXAMPLE STUDY

To illustrate and test the ideas for selecting monitoring sites that were described in Section 5, TSP data for the City of Baltimore and surrounding areas for 1980 and 1981 are listed in Table 18. Figure 29 shows the locations of monitoring sites within the city limits; Figure 30 shows monitoring site locations outside the city limits.

For the purposes of this example, it is assumed that the State of Maryland and the City of Baltimore will cooperatively operate monitoring stations in the city for the following objectives:

- Evaluate progress in meeting and judge the attainment or nonattainment of NAAQS
- Develop and revise as necessary the Maryland Implementation Plan for controlling PM<sub>10</sub>
- Provide data to EPA to meet national monitoring needs and to evaluate the State's management of air quality
- Provide data for model research and development
- Support enforcement activities
- Provide the public with information on air quality exposure and trends
- Provide data to identify and document episode exposure situations.

The annual mean concentrations for 1980 and 1981 are plotted in Figures 31 and 32. Isopleths are also shown to help interpret the patterns indicated by these data. The locations of the eight major point sources with particulate matter emissions in excess of 100 tons/yr are also shown and identified by number. The estimated emission rates for these sources are listed in Table 19. Fugitive emissions shown by squares in the air quality maps are listed in Table 20.

The maximum 24-hour concentration of TSP that were measured during 1980 and 1981 are shown in Figures 33 and 34. The 1981 pattern is based on 15 observations, while the 1980 pattern is based on 10 observations. The patterns of maximum concentration are quite different between the 2 years. The tongue of

TABLE 18. HI-VOL MEASUREMENTS OF TSP IN THE VICINITY OF BALTIMORE  
(MARYLAND AIR MANAGEMENT ADMINISTRATION 1980, 1981)

| Site, county  | Geometric mean    |                    | Maximum<br>(6-day cycle) |                    |
|---|-------------------|--------------------|--------------------------|--------------------|
|   | 1980              | 1981               | 1980                     | 1981               |
| 35. Fire Department Headquarters, City              | 82                | 70                 | 284                      | 203                |
| 38. NE Police Station, City*                        | 54                | 48                 | 138                      | 129                |
| 39. NW Police Station, City*                        | 69                | 56                 | 275                      | 122                |
| 40. SE Police Station, City*                        | 81                | 68                 | 269                      | 166                |
| 41. SW Police Station, City*                        | 65                | 55                 | 201                      | 135                |
| 42. Fire Department #10, City                       | --                | 88                 | --                       | 325                |
| 44. Fairfield, City                                 | 89                | 89                 | 206                      | 310                |
| 47. Canton Pier #4, City**                          | --                | (141) <sup>2</sup> | --                       | (575) <sup>2</sup> |
| 48. AIRMON-02, City                                 | --                | 67                 | --                       | 146                |
| 49. Fire Department #22, City**                     | 82                | (85) <sup>2</sup>  | 222                      | (165) <sup>2</sup> |
| 50. Ft. McHenry, City                               | 103               | 89                 | 195                      | 231                |
| 51. Holabird Elementary School, City**              | (72) <sup>2</sup> | 71                 | (175) <sup>2</sup>       | 161                |
| 52. Westport, City                                  | 93                | 71                 | 178                      | 140                |
| 53. Canton Recreational Center, City**              | --                | (75) <sup>2</sup>  | --                       | (176) <sup>2</sup> |
| 54. I-95, City**                                    | (73) <sup>3</sup> | 73                 | (133) <sup>3</sup>       | 155                |
| 23. Garrison, County                                | 49                | 47                 | 94                       | 93                 |
| 26. Catonsville, County                             | 47                | 46                 | 86                       | 112                |
| 28. Essex, County                                   | 64                | 61                 | 134                      | 136                |
| 29. Padonia, County                                 | 67                | 60                 | 183                      | 114                |
| 33. Chesapeake Terrace Elementary<br>School, County | 66                | 60                 | 147                      | 140                |
| 34. Sollers Point                                   | 79                | 80                 | 145                      | 176                |
| 18. Linthicum, Anne Arundel County**                | (56) <sup>2</sup> | --                 | (81) <sup>2</sup>        | --                 |
| 20. Glen Burnie, Anne Arundel County                | 68                | 61                 | 132                      | 125                |
| 23. Riviera Beach, Anne Arundel County              | 60                | 58                 | 85                       | 137                |

\* Operated on a 3-day cycle, rather than a 6-day cycle.

\*\* Values in parentheses represent only two or three quarters.

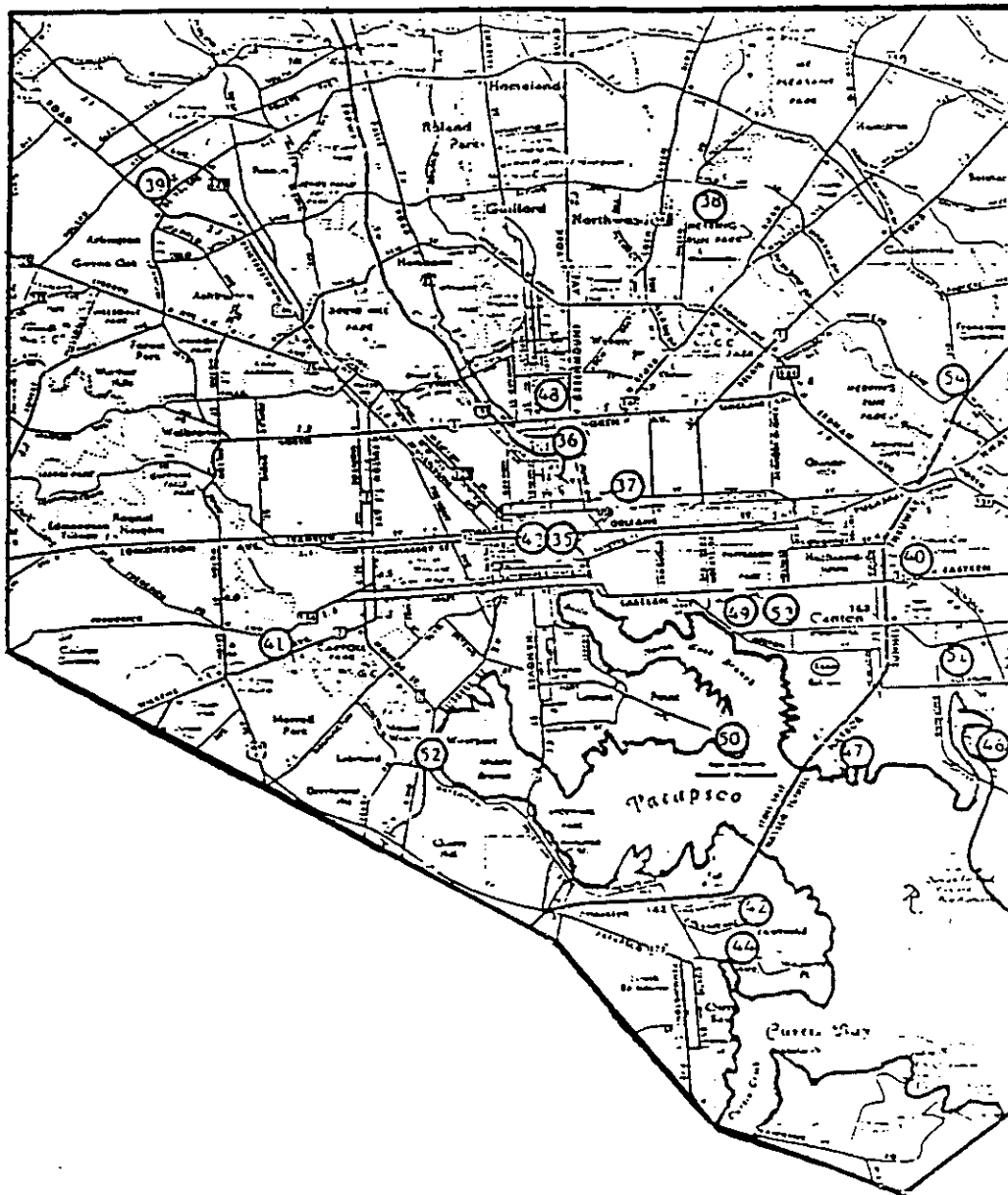


Figure 29. TSP monitoring sites in Baltimore City.



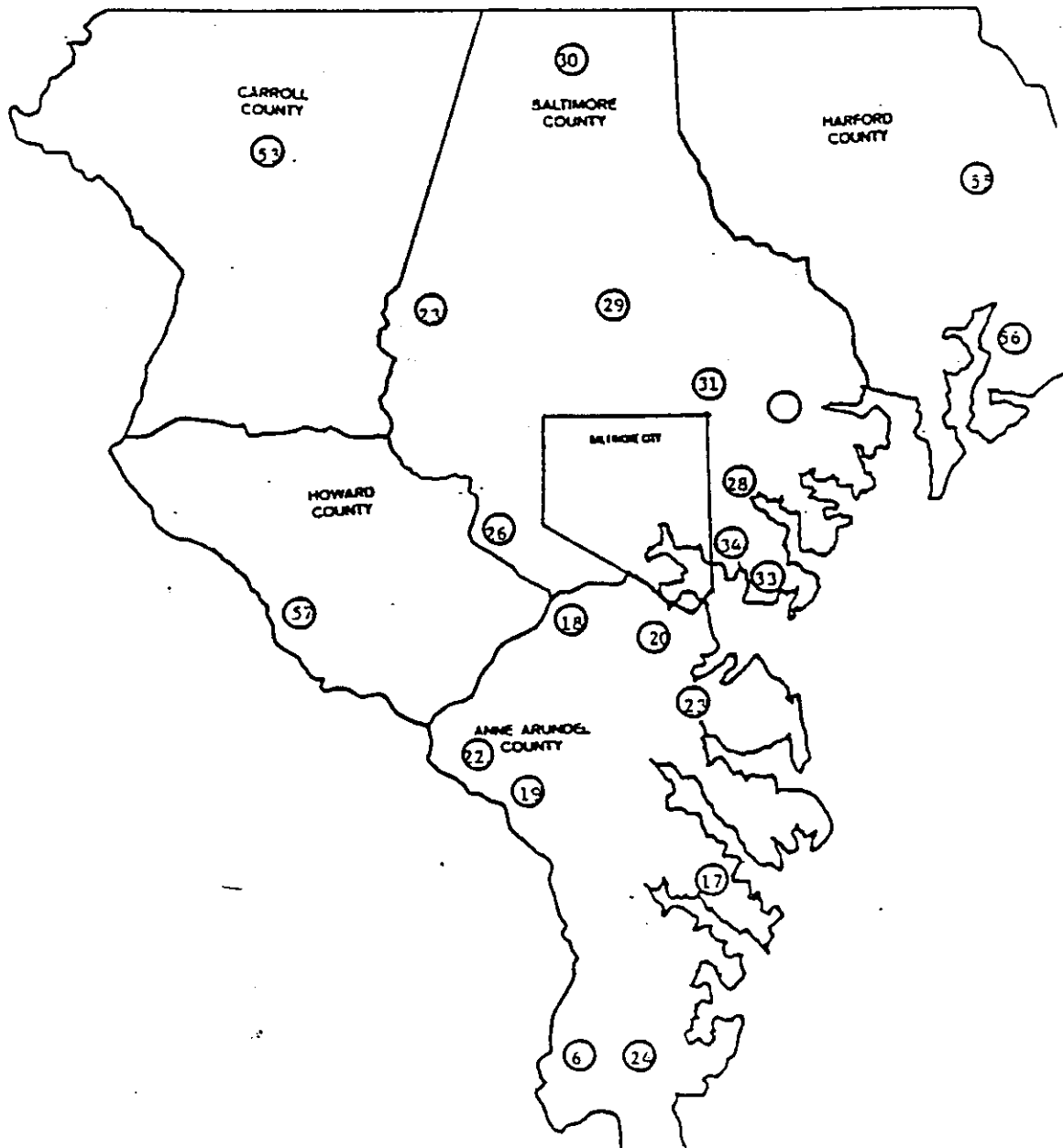


Figure 30. TSP monitoring sites in the Baltimore AQCR, excluding Baltimore City.

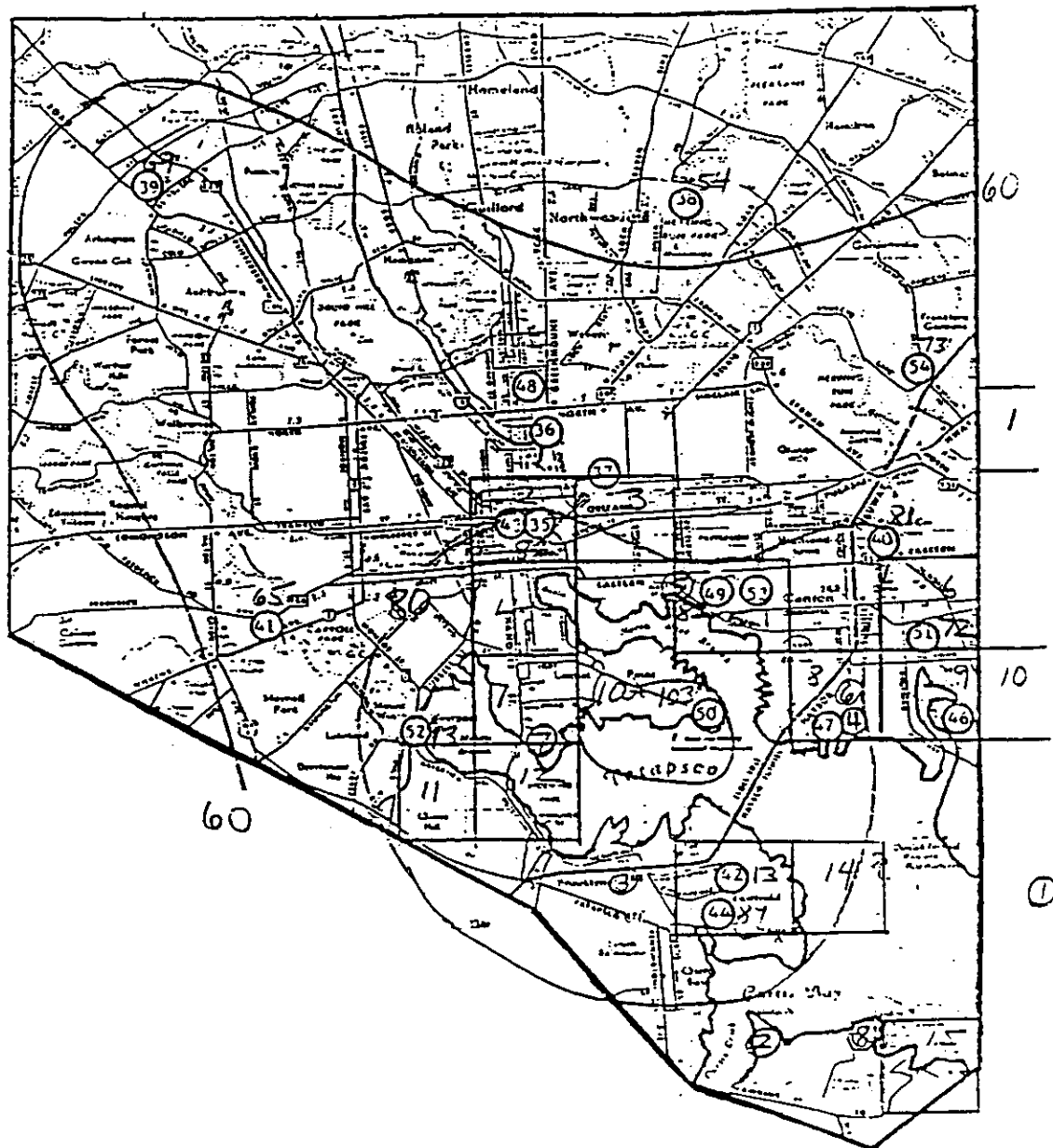


Figure 31. Annual mean TSP concentration for 1980.

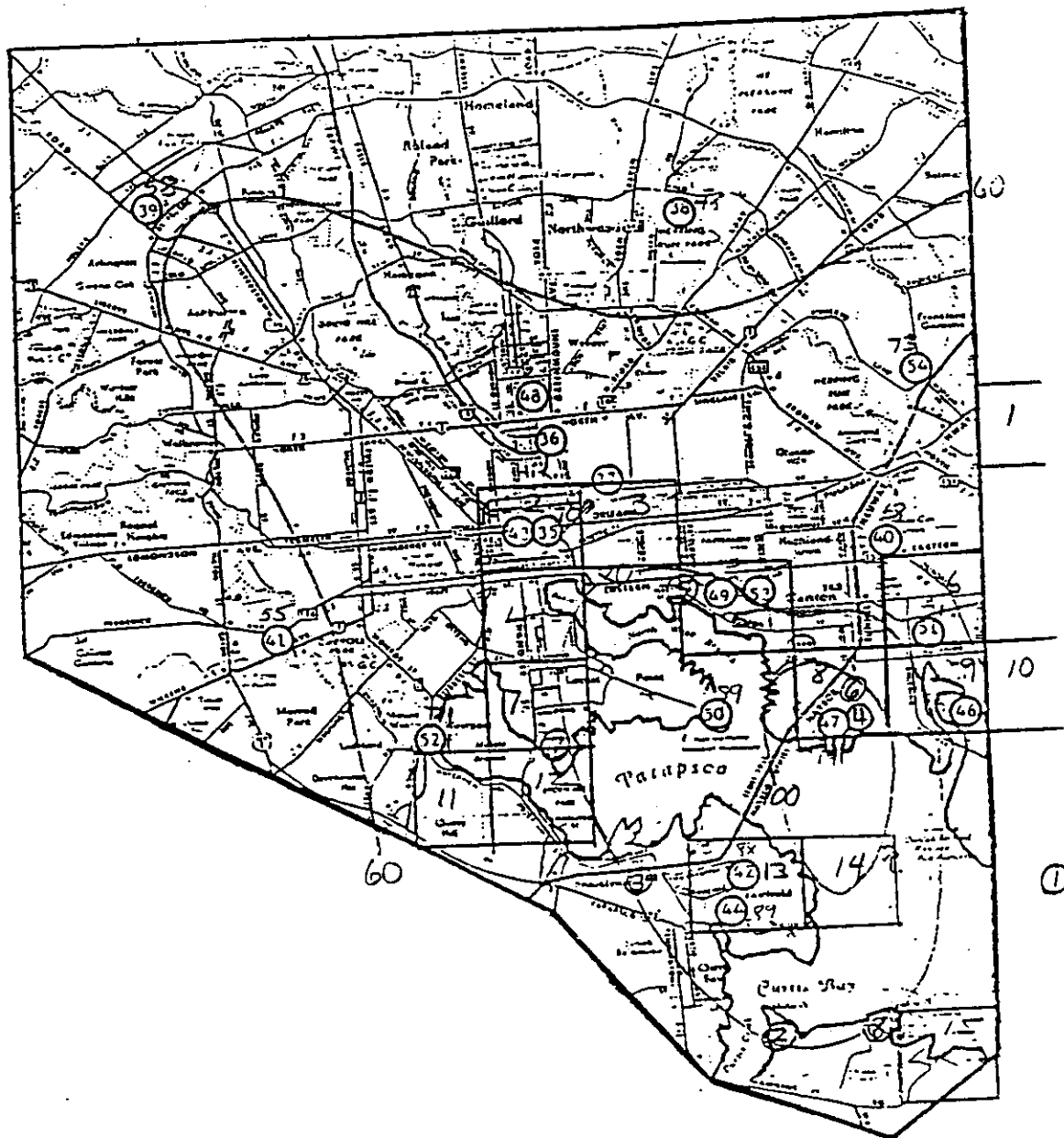


Figure 32. Annual mean TSP concentration for 1981.

TABLE 19. TSP EMISSIONS BY EIGHT LARGEST POINT SOURCES IN BALTIMORE CITY

| Number | Name               | Emissions<br>(tons/year) | Type         |
|--------|--------------------|--------------------------|--------------|
| 1      | BG&E               | 181                      | Fuel burning |
| 2      | Davison Chemical   | 133                      | Process      |
| 3      | General Refractory | 116                      | Process      |
| 4      | Carton Elevator    | 1,475                    | Process      |
| 5      | Allied Chemical    | 145                      | Process      |
| 6      | National Gypsum    | 126                      | Process      |
| 7      | Louis Dreyfus      | 2,193                    | Process      |
| 8      | U.S. Gypsum        | 1,612                    | Process      |

TABLE 20. FUGITIVE EMISSIONS BASED ON 1977 SURVEY  
(Schakenbach and Koch 1978)

| Area<br>identification | Emission<br>rate<br>(tons/day) | Principal<br>sources           |
|------------------------|--------------------------------|--------------------------------|
| 1                      | 11.7                           | Dirt roads                     |
| 2                      | 8.0                            | Dirt roads, construction sites |
| 3                      | 2.2                            | Dirt and gravel roads          |
| 4                      | 4.1                            | Dirt and gravel roads          |
| 5                      | 2.2                            | Dirt and gravel roads          |
| 6                      | 7.3                            | Dirt roads                     |
| 7                      | 2.4                            | Dirt roads, construction sites |
| 8                      | 2.6                            | Dirt and gravel roads          |
| 9                      | 10.9                           | Dirt and gravel roads          |
| 10                     | 2.7                            | Dirt and gravel roads          |
| 11                     | 1.8                            | Gravel roads                   |
| 12                     | 1.7                            | Construction sites             |
| 13                     | 3.8                            | Storage piles, gravel roads    |
| 14                     | 4.1                            | Gravel roads                   |
| 15                     | 2.1                            | Gravel roads                   |

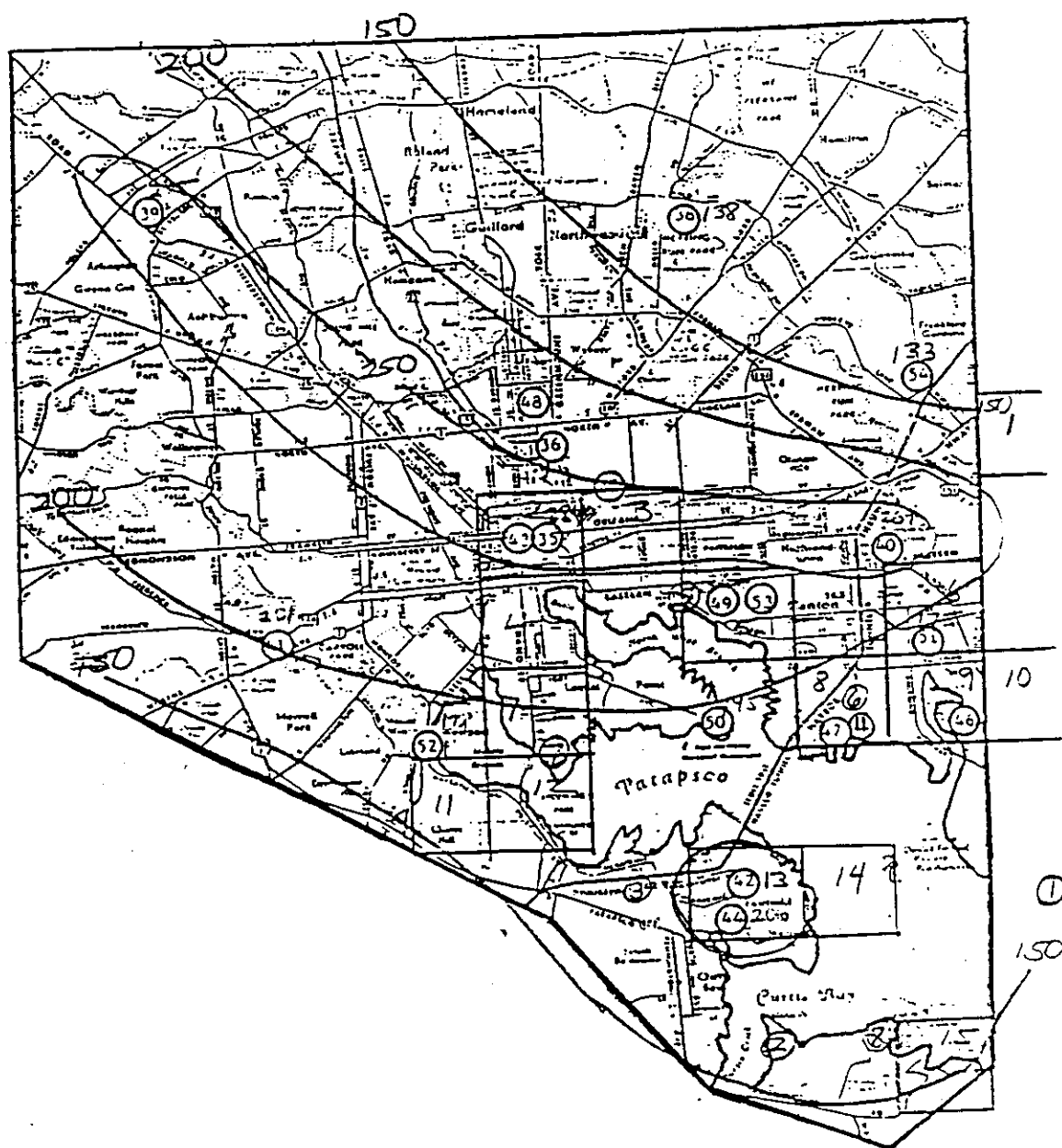


Figure 33. Maximum 24-hour TSP concentration for 1980.

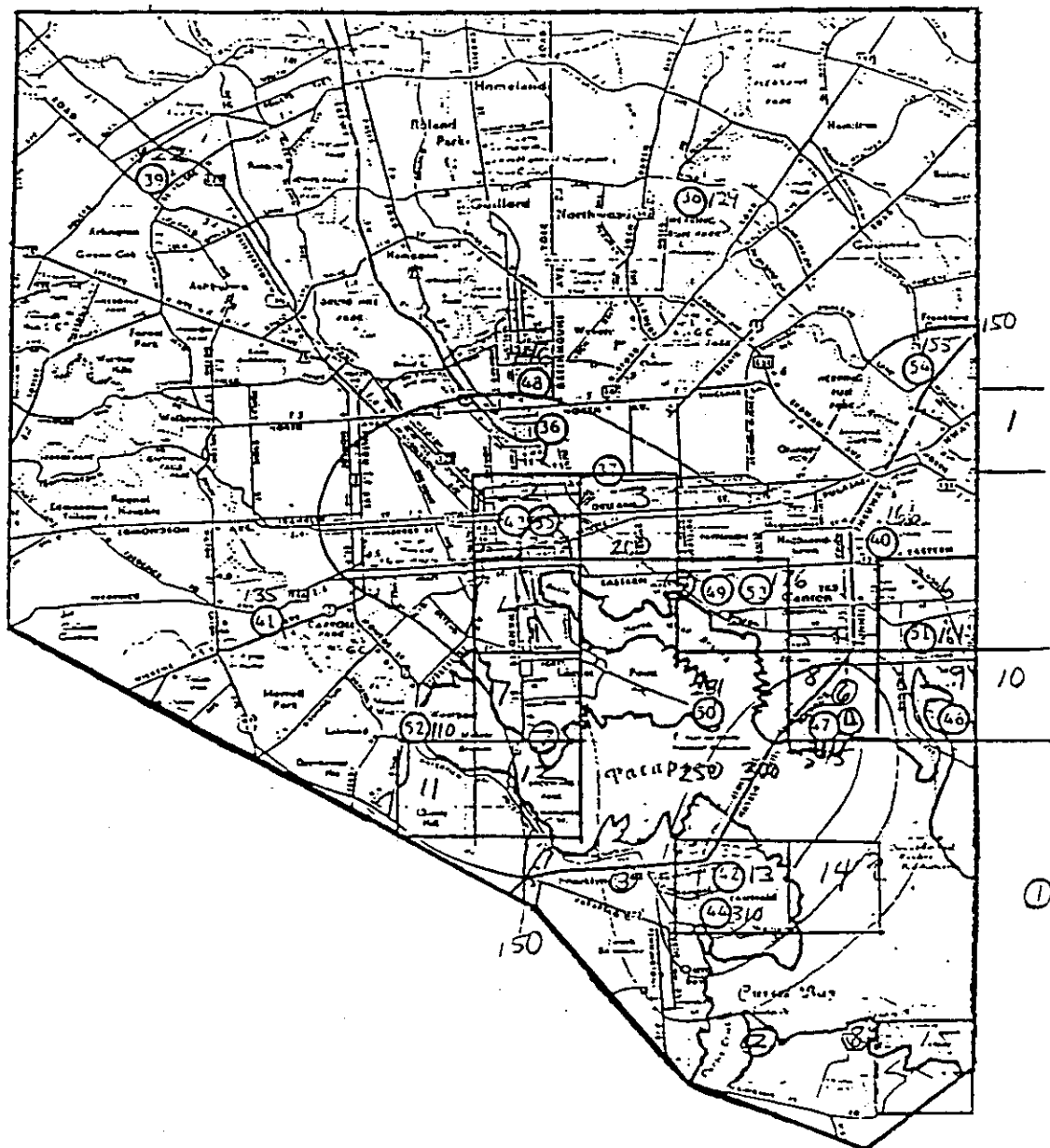


Figure 34. Maximum 24-hour TSP concentration for 1981.

high concentrations shown for the 1980 data is not confirmed in 1981. It is possible that the two high observations to the east and northwest ends of the tongue were not properly sited and showed unrepresentative local influences. The 1981 pattern for maximum 24-hour concentrations is more compatible with the two annual mean patterns, showing a primary peak around the open harbor area and a secondary peak over the primary central city area just west of site 35.

The TSP monitoring data indicate a core area of high concentrations centered on the Baltimore harbor region. The highest point and area source emissions of particulate matter also form a ring around the harbor zone.

Figure 35 is a wind rose showing the frequency of 24-hour mean wind directions with a wind persistence index of 0.85 or greater. (An index of 1.0 indicates a continuous wind direction without variation.) The wind directions with the most frequent occurrence of a persistent wind are west-northwest, west, and northwest. The persistent wind directions closely parallel the orientation of the harbor along the Patapsco River. Therefore, the persistent winds also favor a core of high particulate matter concentrations around the harbor zone. The tongue of high values north of the principal sources shown in the peak 1980 concentrations is not well supported and is not evident in the 1981 data.

PM<sub>10</sub> concentrations may be expected to show a flatter pattern with less pronounced peaks than the TSP data. This is because there will be lower contributions from the larger particles released close to local sources. Monitoring sites farther from the local sources will be less affected by the deletion of larger particles and will show smaller reductions. This will result in a smoother pattern.

At least one site in the harbor area is needed to measure the peak PM<sub>10</sub> concentrations. Since the area is presently out of compliance with NAAQS for particulates, there will need to be sufficient monitors in the area surrounding the harbor to delineate the general shape of a potential noncompliance area for the new PM<sub>10</sub> standards. One strategy would be to select locations northwest, northeast, and south or southwest of the harbor area. In view of the potential for high levels of PM<sub>10</sub> concentrations, there is a need to inform the public of PM<sub>10</sub> exposure levels and trends, to document episode situations, and to support enforcement activities. For these reasons, it is desirable to site at least one and ideally two additional PM<sub>10</sub> monitors in the harbor area. Once the magnitude of PM<sub>10</sub> concentrations relative to PM<sub>10</sub> standards has been established, the siting requirements need to be reevaluated. There is also a need for a background monitoring site. There are many suitable sites that are presently monitoring TSP concentrations. Baltimore County Site 23, about 15 km northwest of Baltimore City, is upwind of the persistent prevailing wind directions. Furthermore, TSP measurements made at this site are indistinguishable from TSP measurements made at a site 35 km to the northwest (site 53) in very rural Carroll County (see Figure 31).

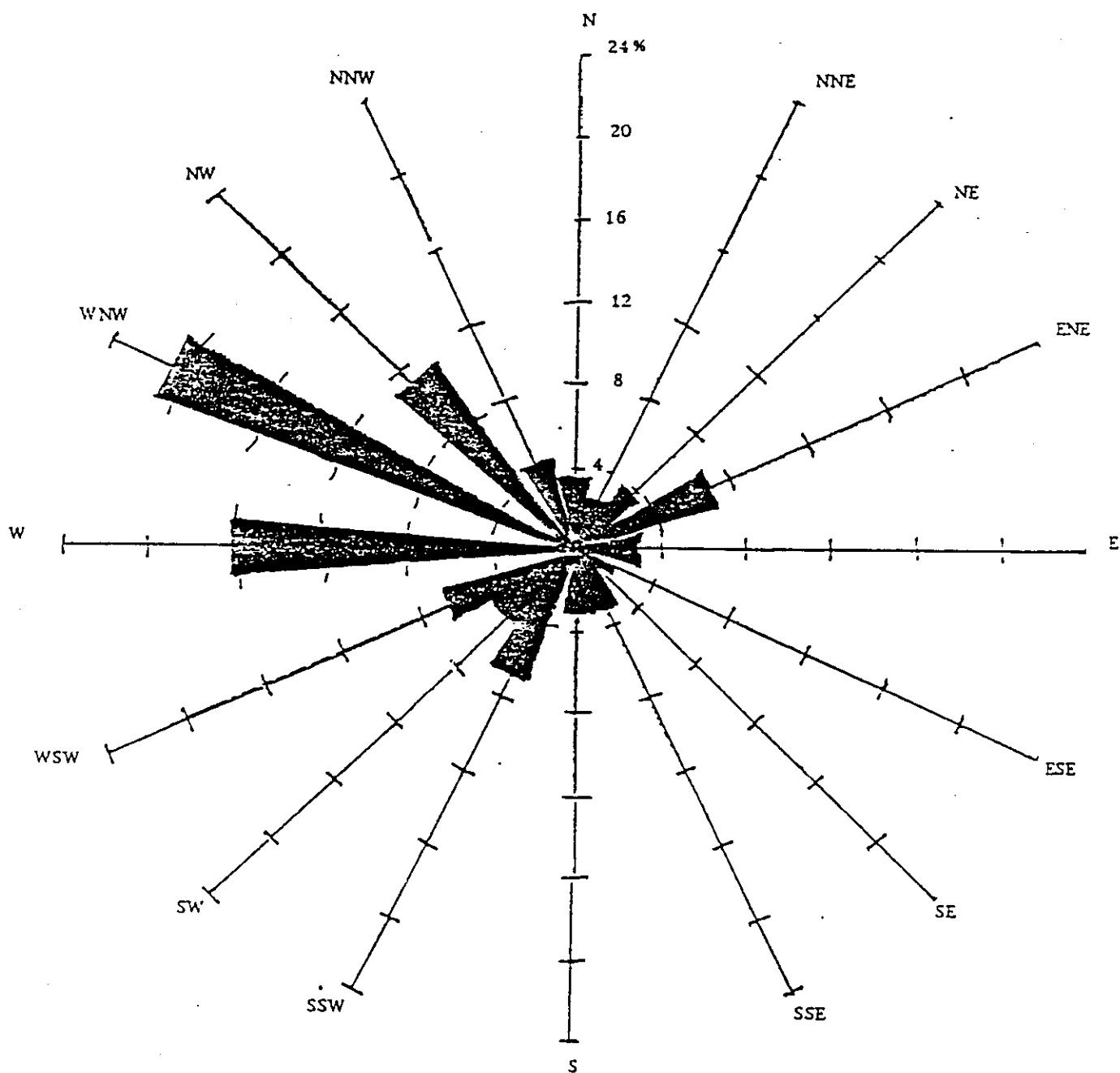


Figure 35. Wind persistence rose for Baltimore-Washington International Airport for 1973-1977 (wind persistence index greater than 0.85) (Pickering et al. 1979).



The preceding discussion describes the development of PM<sub>10</sub> monitoring network requirements where there is adequate TSP monitoring data to define the shape of the expected pattern of PM<sub>10</sub> concentrations. In this situation, modeling is not necessary. The subsequent selection of specific monitoring placements require onsite inspection of potential sites and the criteria described in Section 5.